A LITERATURE SURVEY OF OCEAN POLLUTION

by

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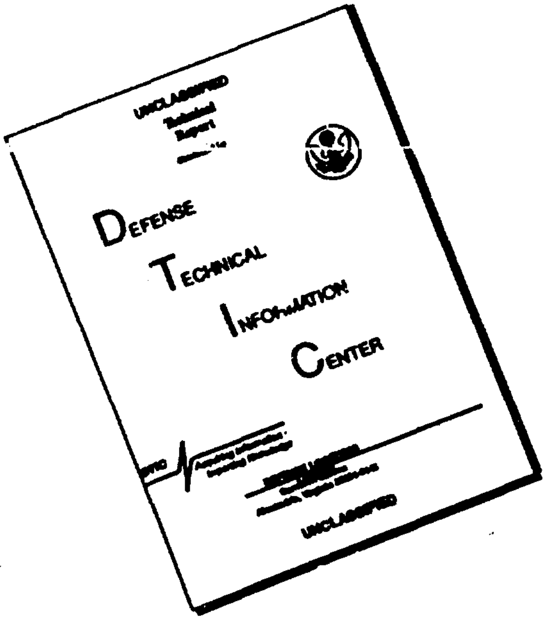

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13. ABSTRACT

Any change in water quality which has an adverse effect on a beneficial use of the marine waters, such as the propagation of fish, shellfish, waterfowl, and other acquatic animals, propagation of kelp and other attached algae, recreational and aesthetic enjoyment, municipal water supply, industrial water supply, navigation, scientific research, and others, constitutes an ocean pollution problem. The present work is a state of the art survey of the past studies on the problems of ocean pollution and to identify areas in which where were notable deficiencies in knowledge.

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Preface

This study was sponsored by the Ocean Acoustics Program at Catholic University under Contract N00014-69-A-0432, Office of Naval Research. Since there is an intimate relation between aspects of ocean sound propagation, ocean noise and the oceanic environment itself, it seemed important to take a survey look at the subject of ocean pollution.

Frank Andrews
Principal Investigator

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I. INTRODUCTION

. Any change in water quality which has an adverse effect on a beneficial use of the marine waters, such as the propagation of fish, shellfish, waterfowl, and other aquatic animals, propagation of kelp and other attached algae, recreational and esthetic enjoyment, municipal water supply, industrial water supply, navigation, scientific research, and others, constitutes an ocean pollution problem.[11,13,33]

. For centuries man has used the oceans as, among other things, a receptacle for waste. While it is true that the ocean has an inherent nature capacity to assimilate certain amounts of waste material without lasting or no resulting harm to the ecological system, but in many instances this limit has either been exceeded or is threatened. Pollution has taken its toll in the last half century. This has been evidenced by the increasing disappearing of oyster and clam beds, the fishery areas, and the bathing beaches around many coastal and estuarine areas. The unknown and unseen adverse and irreversible effects which we create in the environment can hurt us and our children and reduce the range of choice for our future generations.

. The present work is a state of the art survey of the past studies on the problems of ocean pollution and to identify research areas in which there were notable deficiencies in knowledge. Available literatures, documented as well as unpublished, has been surveyed pertaining to all phases of ocean pollutions. Chapter II is a general description on ocean pollution of the world today. The chief pollutants and their sources are discussed in Chapter III. The effects and the control of various types of ocean pollutions are given in Chapter IV and V, respectively. The areas of research need are indicated in Chapter VI.

Chapter VII is the conclusion. A list of terminology, often encountered in fields related to ocean pollution, is given in Chapter VIII. The bibliography which, given in Chapter IX, is by no means complete. To review and outline all the related literature is far beyond the purview of this work.

II. SITUATIONS

2.1 The Ocean[6,10,16,21,22]

The seas and oceans cover nearly three-quarters of the surface of the earth. The water is in constant movement due to the rotation of the earth, the pull of the moon and sun, the heating in equatorial areas and cooling in arctic seas.

Marine waters may be divided into three zones (Fig. 1 and 2):

A. inshore areas: including the intertidal coasts and partially enclosed areas such as estuaries, harbors, bays and marshes.

B. the continental shelf

C. the deep sea

The ocean has many resources and is offering one of man's great hopes for future food supplies[34] (Fig. 3, 4, 5 and Table 3). The photosynthetic production within the ocean surface layer (about 100 ft. deep) is vitally important to all marine life. The phytoplankton produce about one-fifth of the earth's oxygen.

2.2 The Past Practice

It has been generally assumed that the ocean is so vast that all the waste products of mankind could be discharged into the sea without any noticeable effect, provided only that the points of discharge were distant enough from shore.

Most sanitary work was directed almost exclusively on fresh water streams and lakes in the past. Salt water in the open ocean or brackish water in tidal estuaries received scant attention due to little effect on their subsequent uses.

Prior to 1950 literature on man-made pollution of the marine environment was relatively limited; yet much of the world's wastes are discharged into saline waters. The disposal of sewage and industrial wastes by coastal towns is usually done by the mixing of the effluent from ocean outfall sewers with the sea water.

2.3 The Present Trend

There is an explosive growth near the ocean areas. People move to the coasts in seeking the amenities and recreational opportunities of the seashore (Table 1), as well as the convenience and advantages there for certain kind of industry. About 45% of the U.S. population resides in counties adjacent to the ocean areas[32,33] and this will increase to more than 50% by the year 2000[53].

More than 11,000,000 Americans now live in communities that discharge raw sewage into passing waters[33]. As the pressure to maintain clean inland waters mounts, wastes are moved further to sea by pipelines, tankers, and barges. There is an increasing use of the ocean as dumping grounds for man's garbage and industrial wastes[243].

Worldwide activities in the ocean have also stepped up rapidly in recent years[14]. (Table 2a) With the growing use of the sea lanes for commerce and of the sea-bed for mineral extraction (Fig. 4), and ever-increasing size and variety of cargo ships and tankers (Table 2), the threat of pollution to the marine environment from deliberate or accidental release of wastes of noxious cargoes becomes more acute every day (Table 7).

The increasing number of atomic energy establishments throughout the world creates another hazard condition (Fig. 6 and 7). The present radioactive level in the ocean has already been described as maximum permissible.[304] The toxicity of radioactive waste can linger for centuries.

It should also be recognized that the ocean is the final resting place for almost all of the waste products that we discharge into streams or into the air. Thus, all discussions on pollution and its effects must end with the ocean.

2.4 Major Affected Areas

A. Estuaries, Bays, and Marshes[55,56]

Estuaries are the breeding grounds and nursery for many important species of fish and wildlife. There is clear evidence that the influence of estuaries may extend well into the ocean basins.

Estuaries are significant to human welfare through their role in transportation, production of food, waste disposal, and various recreational pursuits. Seven out of ten world's largest metropolitan areas are developed near estuaries. They contain over 55 million people and enormous industrial activities[32,33]. In the U.S., about 80%-70% of the Atlantic and Gulf of Mexico Coasts and 10%-20% of the Pacific Coast are composed of estuaries (total about 850-900 bays and estuaries). They consist of 40 out of the 110 U. S. metropolitan areas and represent one-third of the total U.S. population.

These waters have become adversely affected by human activities[229,233,234,264]. In the United States about 1.2×10^6 acres of estuarial shell fishing grounds have presently been declared health hazards by the Public Health Service[29].

B. Coastal Region[32,33,308]

Population and industry tend to concentrate in coastal communities. Nearly every coastal community in the world discharges sewage, raw or treated, into the ocean[308]. At least nine U.S. counties with populations of over 50,000 empty their sewage, without treatment, directly into the ocean. The discharge endangers public health and creates a public nuisance. The waste effluents from industry often cause severe damage to marine life.

2.5 Major Incidents

Various types of pollution incidents happen frequently all over the world. The following ones stand out as representative. It should bear in mind that it is not these spectacular local disasters that are significant so much as the general trends, the stealthy deterioration of environmental conditions in sections of the sea of vital importance for its living resources[40].

Source	Cause	Description
Oil tanker	Stranded	March 18, 1967, Torrey Canyon, off Cornwall, England, 30 million gallons crude oil spill; clean-up cost about $8 million; about one hundred thousand birds and millions of fish killed; affected areas went up to French coast[171,191,207,217].
Oil tanker	Stranded	March 3, 1968, Ocean Engle; in San Juan, P.R. Harbor; total damage about $10 million; affected San Juan Bay and neighboring coast, and extended about 3 miles north into Atlantic Ocean[175].
Oil tanker	Grounded	1968, German Esso Essen, off South Africa; discharge 12-15,000 tons of crude oil; massive beach contamination.
Oil drilling	well blowout	January 28, 1969, Santa Barbara Chennel, about 1-3 million gallons oil spill[205], contaminated over an area of 800-1,000 sq. miles; massive bird death 165,188,202,203.
Oil from shore installation	storage broken by storm	December 1966, Long Beach Harbor, California, about 200 barrels of oil spill; contamination of Harbor and death of waterfowl.

Source	Cause	Description
Oil from handling operation	Unloading	1967, Desert Chief, in York River, Va., 500-1200 barrels of crude oil spill; contaminated recreational beach and waterfowl.
Oil from unknown source	unknown	1967, Cape Cod, National Seashore, 30 miles contaminated coastline; death of ducks and waterfowl.
Atomic accidents	bomber crash	January 17, 1966, near Palomares, Spain, 4 H-bombs, one intact, two released radioactive materials near shore, the fourth lost in the ocean and was retrieved[298].
	Sink of nuclear submarine	April, 1963, Thresher, off U.S. Atlantic coastline, with nuclear warhead. May 1968, Scorpion[298].
Atomic waste dump	Deep ocean currents	Off Portuguese, deep sea dumped nuclear waste package was brought to surface by upwelling and currents; caused international concern[34].
Industrial waste	Chemical discharge	June 1969, on the mouth of River Rhine, Germany, Organophosphorus poisoning (a form of nerve gas used in manufacture of insecticide); about 40 million fish killed; many death of rats and cats; caused international concern[265].
Industrial waste	Chemical discharge	December 1968, at Long Harbour on Placentia Bay, Newfoundland, Sweden; phosphorous plant effluent poisoning; death of fish and sick animals such as rats and cats; temporary close down of the plant[265].
Industrial waste	Chemical discharge	Japan coastal waters, mercury poisoning; caused death and "epidemic" neurological disease from eating fish[269].

III. POLLUTANTS

3.1 The Chief Pollutants

Any additive that changes the quality of the water so as to interfere with some of the beneficial use of the water is a pollutant.[13,40]

The main pollutants are oil, biocides, thermal effluent, nuclear waste, industrial effluents, domestic sewage, spoils from dredging and mining, solid objects and miscellaneous unspecified substances.

3.2 Major Sources[60,214]

A. Oil Spill

Oil spill is the most pervasive form of marine pollution. There is scarcely any coast whose beaches have not been affected at one time or another. It is estimated that about 1-100 million tons of oil are added to the oceans each year.[214]

The U.S. Coast Guard estimated that 10,000 spillage of polluting incidents annually in U.S. waters. Oil spill leads all other categories by a ratio of about three to one.[185]

The main sources are:

a. Tankers and ships

Accidents

Situation. An example of the condition of sea traffic in the U.S. ports is illustrated by Table 6. There were about 10,000 tanker visits to the U.S. ports in FY 1966, about one out of every five vessels transport oil. In addition, there is also domestic coastline traffic.[14] In 1967 there were 458 detected violations of oil pollution statutes, of which 63 involved tankers, 56 dry-cargo ships, 56 navy ships.[221] There were about 500 tanker collisions in the past 10 years in U.S. waters.[14] A typical casualty record is shown in Table 7.

Potential hazard

- Growth of the world fleet of supertankers: New tankers are 3-5 times larger than the size of Torrey Canyon (with 30 million gallons of oil spill). It has grown from the 16,000 dwt World War II standard to the recently launched 312,000 dwt Universe Ireland class, and vessels of 500,000 to 800,000 tons are being designed.
- Increasing sea traffic: Caused by the growing sea activities and the number of ships and tankers (Table 3).
- Difficult sea routes: Some new developed sea routes such as the route from North Sea Alaska to the States.

All of these developments tend to create more hazard to the oil pollution accidents which will cause serious local pollution problem.

Sunken ships

Situation. In the U.S. alone, there were about 428 ships sunk off the East Coast, in the Caribbean and Gulf of Mexico during World War II. Total tonnage was 2,270,000 tons of which nearly half was tanker[204]. It was also estimated that there are 61 sunken tankers containing nearly 10^6 tons of oil close by the Atlantic Coast[205].

Potential hazard

- The low rate of leakage probably makes the problem less severe.

b. Offshore oil drilling and production operations:

Situation. Since 1954 there are 8,000 oil wells drilled offshore of the U.S. continental shelf, 8 oil and 17 gas blowouts. If the present rate continues, 3000 to 5000 wells will be drilled annually by 1980.[215] Major operations in the U.S. are at the Gulf of Mexico, the Southern California coastal waters, Cook Inlet in Alaska and East Coast. The causes of oil spill are:

- blowout of well
- dumping of oil-based drilling muds and oil-soaked cuttings
- loss of oil in production, storage and transfer
- pipeline failure along ocean floor from offshore flatform to storage facilities
- leak from suspended or abandoned oil well
- leak from drilling well or production well

Potential hazard

- Increasing number of offshore terminals
- Lack of adequate knowledge presents high risk of blowout
- The localized pollution is serious

c. Waste oil

Situation. Discharge from tankers and non-tankers. Spill comes from operations such as emptying salt water ballast, pumping bilge waters, cleaning oil tanks, transferring and handling oil cargoes. An order of 3×10^6 tons/year of oil is dumped by the tanker ballast process, and about 5×10^5 tons of oil/year from non-tanker ballasting process.[205]

- Gasoline service station and municipal sewage system: Most of the oil waste comes from storm sewer overflows.
- Industrial oily waste: The Bureau of Census reported that there are over 10,000 industrial plants which are major water users.

Potential hazard

- Increasing number of ships (Table 3)
- Presenting a worldwide pollution problem.

d. Shore installations

In 1966 there were about 40 percent of the 2,000 oil spills in the U.S. caused by discharges from shore installations. The causes are mainly from industrial transfer and storage such as tank rupture, levee and dike failure, pipeline break and human failures.

e. Natural sources

In the U.S. natural seeps offshore have been observed off California coast and in the Gulf of Mexico. The rate of flow is unknown[205].

B. Waste Disposal

a. Solid waste dumping

Situation. The main sources are from barge delivered dumping of sewage and industrial sludge. The practices have increased fourfold over the past 20 years. More than 48 million tons of wastes were disposed of in the ocean around the U.S. in 1968. Dredging spoil and industrial sludge are two major pollutants (Table 5a,b). They are dumped from about 126 ocean disposal sites--42 in the Pacific, 51 in the Atlantic, and 33 in the Gulf of Mexico, and 20 coastal cities used in 1968. These disposal sites are located at distances from 15 to 100 miles offshore in general[243].

Potential hazard

- Increasing industrial waste dumping: Many of them are being barged from interior areas of the nation. Industrial wastes and sewage sludges are the largest factor contributing to the 27.5% increase in tonnage over two five-year periods (1959-63 compared with 1964-68)[243].

- Many chemical wastes occur in the form of heavy sludges that are extremely difficult to eliminate by treatment (e.g., petrochemical and metal refinishing products) are dumped untreated into the ocean.
- There is no adequate knowledge about the dumping of toxic chemical war materials such as nerve gas.

b. Industrial chemical wastes and biocides

Situation. Main sources of chemical wastes are the effluents of most factories and mine drainage. Many of these effluents contain toxic chemicals such as sodium chloride and sodium sulphide from syrup and sugar refining plants, sulfite compounds from pulp and paper mills, chloride and sulphates from metal foundries, and other damaging chemicals from petroleum refineries, electroplating plants, agricultural chemical plants, etc.

Toxic inter alia mercury or phosphorous, lead, and other chemicals at a dangerous level have been found in the coastal waters and the estuaries[33,237,240]. Pesticide residues in concentrations of 0.1-5 parts per 100 million have been found in the major river systems of the U.S.A.[269]

Pesticide and other agricultural chemicals come into the marine waters by run-off from land, direct use, disposal of used containers in rivers and streams, storm sewer overflow, discharge of manufacturing factories, and ship discharge.

Potential hazard

- The increasing production of chemicals (Table 4) and the wide use of agricultural chemicals (such as pesticides, insecticides, fungicides, arsenic salts, etc.)[29] create a dangerous pollution problem.
- Plastic chemicals such as polychlorobiphenyls and chloronitrobenzene and others derived from the plastic industry present another form of pollution. Their components do not break down easily.[269] For Example, Chloronitrobenzene, discharged into the Mississippi at St. Louis, Missouri, was still demonstrable in water drawn at New Orleans, Louisiana.[269]

c. Municipal sewage and animal wastes

It has been estimated that sewage of 8% of the U.S. population is discharged directly into waterways[253,308]. Eighteen percent receive only primary treatment and one-third of the population uses cesspools and septic tanks.[308] The sewage usually discharge through outfalls. In California, there are more than 125 communities dispose sewage effluent through submarine outfalls (Fig. 16).

The increasing amount of detergents from domestic sewage creates a pollution hazard.

d. Overboard dumping of shipboard wastes[246,260,271]

It threatens harbors and coastal waters where large numbers of ships are found.

C. Atomic waste

The disposal of radioactive wastes into seas are being practiced by many nations[296]. Five member countries of the European Nuclear

Energy Agency had disposed of some 1,100 tons of solid wastes with a total activity of approximately 800 Ci, at a depth of 5,000 meters in the eastern Atlantic Ocean by 1967.[288] Prior to 1967 the U.S. Atomic Energy Commission disposed radioactive wastes in the sea. The majority of radioactive disposal sites were in the Atlantic. A recent review of the status of radioactive waste disposal in the U.S. is given by Parker.[303]

. Nuclear power plants: such as the power plant cooling sites, in vessels, in space vehicles, natural resources recovery system, and in desaltation plants.

. Research, military, hospital, and industrial laboratories: For example, large accumulation of radioactive substances has been found on the sediment near the British Atomic Energy Authority processing plant in Windscale. It has released low level wastes into the Irish Sea since 1952.[280]

. Experiments to determine various physical characteristics of the ocean: Many artifical radioactive isotopes have been used as tracers.

. Nuclear explosions: Majority of radioactive particles from atmospheric nuclear bomb testing settle out of the atmosphere into the sea.

. Ore extraction and dressing plants

. Accidents: such as due to malfunction discharge or escape of polluted water from atomic installations, nuclear vessels, atomic bombs, dumped waste packages, etc. Since 1955 about 33 such accidents have happened to the U. S. alone.[298]

Potential hazard

- Increasing number of nuclear power plants: The estimated growth is:[308]

Year	Radioactive level of waste
Present level	80 million curies
by 1980	10 billion curies
by 2000	65 billion curies

More and bigger plants are planned on the coasts and estuaries to be available to coastal waters. (Fig. 6, 7).

- Proposed nuclear desaltation plants.
- The potential danger of the dumped waste package due to the underwater currents, future fishing, dredging and cable laying and other activities.
- The pollution is serious because of its accumulating effect.

D. Thermal Discharges

Thermal pollution is the effect of the unnatural temperature alternation in the aquatic environment.[344,348] The sources are:

- Nuclear power plant: It releases about 10,000 Btu of heat per Kwh.
- Fossil fuel electric power plant: The thermal efficiency is higher than the nuclear power plant. It releases about 6,000 Btu per Kwh.
- Factories and desaltation plants.

Potential hazard

Since World War II, the electric utility industry load requirements have doubled each decade. Seventy-five percent of those loads were generated in thermal plants.[373] The enormous power demands predicted for 1973 and later will be largely nuclear energy with peaking needs fulfilled by pump storage and internal combustion devices[376]. New power installations will have to be near the shores of the sea or great lakes in order to satisfy the enormous needs of cooling water[376] (Fig. 6 and 7); otherwise, some of the rivers in the U. S. could reach their boiling point by 1980 and may even evaporate by the year 2010.[347]

E. Exotic Cargo Ships

Many cargoes such as molten sulphur, methane, pressurized gas and others present a potential pollution hazard. Their behavior and hazard of massive release are not known.

F. Man's Activities

The sources are:

a. In the watershed

The competition for the use of available river water causes diminished river flow downstream. For example, the planned river flow diversion program in Texas will divert the water of the Sabine River, the Neches, the Trinity, the Brazos, the Colorado, and the Nueces from east Texas to west Texas. No water will escape to the coastal estuaries.[321] The California Sacramento-San Joaquin region program also proposes plans for damming, diverting, filling and vast modifications of large areas.[313]

b. <u>In the estuary and coastal line</u>[311,312]

- Reclamation of estuaries, lagoons, and marshes: 45,000 acres of tidal wetlands were lost between 1954-1963 along the north-east coast from Maine to Delaware[33]. Twenty sq. miles of Tempa Bay in Florida have been filled for residential property.[33]
- Basin modifications from shoreline construction[320], dynamiting,[310] dredging and cutting of waterways.[314]

c. <u>Mining operations on the sea bed</u>

Beside the danger of pollution by oil well blowouts, there are other possible adverse effects from seismic operation, disposal of industrial spoil from mining, etc.

<u>Potential hazard</u>

- Diminished river flow into sea by the competitive use of river waters upstream.
- Increasing filling in of marshes and bays for the real estate development
- Increased channel dredging for marinas and harbors for bigger vessels
- Shoreline modifications for beach recreational development
- Potential danger of spoil by future submarine mineral exploitation (Fig. 4, 5 and Table 2).

All of these increased activities will cause alternations of salinity and silt distribution of marine waters. They are special types of ocean pollution.

3.3 Behavior and Fate of Pollutants

The oil in the water usually experiences dispersal by evaporation, emulsification and sinking after coating sediments, and destruction by microbial oxidation.[209,226]

Radioactive waste moves in the water as follows: initial dilution, dispersal, transport, transference from liquid phase to sediments, movement from suspended sediments to bed sediments, resuspension from bed sediments, sorption on plants and animal forms.[283]

In general, pollutants in the ocean undergo the following phases[50]:

A. Dilution and dispersion by physical processes

B. Chemical and microbiological degradation

C. Reconcentration of pollutant through biogeochemical processes[283]

D. Uptake, accumulations, and transmittal of chemical species through food chain (Fig. 9, 10)

The interrelationship is illustrated in Fig. 8.

IV. EFFECTS

4.1 Introduction

There are two types of effects:

A. Acute effects:

The effects often appear in a pollution incident. It usually causes death, sickness and disease to marine life and human beings, and involves economical damage. The effects are easy to measure.

B. Chronic effects (sublethal):

The effects though difficult to measure, nevertheless, are of most importance. The whole ecosystem and marine communities may be affected by changes in behavior, reproduction, enzyme activity, biomass, species, and in energy flows[50].

4.2 Effects on Man[60]

A. On Aesthetic Enjoyment

This can be affected by oil pollution, sewage and industrial effluent and sludge dumping.

B. On Quality of Marine Products

Effects are tainting of flavors, undesirable modification of texture or color, toxicity, and induced infestation by parasites of fish.

4.3 Effects on Marine Biology

Marine animals are especially susceptible to pollution. Marine life can be affected by:

A. Effect Due to Salinity Alternation

Cause:

. diminished river inflow and changed circulation pattern of estuary and coast waters by engineering works such as damming rivers, draining marshes or opening cuts.

- desalination plants

Effects

Certain marine animals have been observed to be sensitive to salinity, for example:

- Marine fishes such as menhaden (an important commercial fish) live their younger life in lowered salinities
- Oysters thrive in regions of lesser salinity because they are better able to survive than their predators or disease causing organisms
- Shrimps depend on the lower salinity estuaries for protection during their early life.

B. Effect Due to Temperature[338,358,361,372]

Cause:

Electric power plants, desalination plants and other industrial effluent.

Effect

- Most larval forms of marine organisms are very sensitive to temperature changes[367].
- The optimum temperatures for tropical species are often only a few degrees below the lethal temperature (they usually don't thrive at 80°F, the lethal temperature is about 93°F)
- Trout eggs will not hatch if incubated in water warmer than 14.4°C.[358,359,381]
- Soft shell clam mortalities due to thermal effluent were observed[368]

. The metabolic rate, reproduction activity and migration and sprawning of certain marine animals were also affected.[359,382]

Possible benefit

If controlled properly, thermal effluents may be used for promoting artificial culturing of fish and shellfish and to keep navigable waters free of winter ice.

C. Effect Due to Oxygen Content[45,46,82,244]

Cause

Degradation of organic material uses up oxygen. Large quantity of biological and chemical wastes such as sewage or paper mill waste will cause depletion of DO. Thermal effluent will also affect DO and BOD.[331,344,366]

Effect

If the oxygen content is sufficiently low, some bacteria can use the organic matter and the sulfate in seawater to produce hydrogen sulfide gas, which are deadly to marine life. In many estuaries there is a pollution barrier of deoxygenated or contaminated water which effectively prevents the passage of certain migratory fishes such as salmon.

D. Effect Due to Change of PH

Seawater is buffered by the carbon dioxide content. The acidity does not change under ordinary conditions. Any change externally caused is disastrous to marine life.

Certain waste acids from industrial effluent or mine drainage will change pH in local waters.

E. Effect Due to Petroleum[211,214]

Oil pollution affects:

a. Waterfowl and other wildlife

Oil pollution is more harmful for marine birds than for fish. It causes disastrous effects upon individual species as well as upon large populations. The general effects are loss of buoyancy, loss of body heat, exhaustion, starvation and exposure. The chances of survival for affected birds is very small. In the Santa Barbara blowout there were 1725 marine birds treated, only about 235 lived.[165,202,203,214]

b. Fish and shellfish

Petroleum products and derivatives are toxic to fish and shellfish. Surface feeding fish especially easily become toxic and unfit for human consumption. Effect on intertidal life such as mussels and barnacles is light. The sublethal effect may be more important to the ecosystem.

c. Marine plants and other life forms

Oil kills plants such as seaweed. However, the growth of marine algae is often enhanced. The species and composition of bacteria in the marine water are also affected. The deposits of oily sludge on the bottom may affect sessile, benthic dwelling forms and cause potential damages to the ocean floor as a main food supply.

d. Economy loss

- Cleanup cost: About $8 million were spent for Torrey Canyon spill, and $4.5 million for Santa Barbara spill. Cleanup cost is estimated to be $1.35-3.00/gallon in harbor and $1.00/gallon in open sea.[170]
- Damage of shoreline properties and boats
- Affecting recreation beaches, harbors, ports and marinas

e. Large polluted sea waters can change the thermal reflectivity of oceans, and cause meteorological changes.

F. Effect Due to Turbidity

Cause: Dredging[309,322], sewage and industrial effluents, sludge dumping, sea bed exploration and exploitation.[310]

Effect: Turbidity interferes with the photosynthetic activity of marine plants which produce oxygen.[317] The existence of fixed organisms such as oysters will be threatened.

G. Effect Due to Solid Materials

Cause: Sawdust, bark chips, wood fibers, sewage solids, industrial sludge, wreck automobiles, dredge spoils, sea bed exploration and exploitation.

Effect:
- Settlable materials coat the bottom and prevent the growth of bottom living organisms such as shellfish. It was reported that spoil material deposited on the bottom covered an area at least five times that of the defined disposal area.[309]
- The degrading of large organic materials will cause depletion of oxygen.

Possible benefit

Some objects such as old tires and cars can be good artificial fishing reefs and may be suitably used as spat setting surfaces for oysters.

H. Effect Due to Tainting Substances

Petroleum and other chemicals can render fish unuseable because of the offensive or objectionable taste. Pathogenic bacteria discharged with human wastes accumulate in oysters and make them unfit for human consumption.

I. Effect Due to Nuisance Organism

Cause: Municipal sewage, some industrial waste, agricultural runoff.

Effect:
- The nutrients (such as carbons, nitrate, sulfate, potassium, and phosphate) often cause rapid growth of undesirable organisms (such as massive algal blooms or so called "red tide").[258] These organisms can crowd out the more desirable species and upset nature's delicate ecological balance. They also absorb large amounts of oxygen from water when they die; this often causes fish kills.
- The increasing number of bacteria from sewage endangers public health. Virus was found in sea water and shellfish. They can cause enteric illness.[236,253,254]

Possible benefit

If properly introduced into the biological deserts of the ocean, these "rich" wastes may increase the ocean's productivity areas.

J. Effect of Toxic Substances

Cause: Industrial wastes (contain mercury, lead, zinc, copper, arsenic, silver, chromium, plastics, synthetic compounds, acid, etc.) agricultural runqff (contain fertilizers, arsenic, etc.), domestic sewage and oil pollution cleanup (detergent), (Radioactive materials and biocides will be discussed in other sections).

Effect:
- All of these substances are highly toxic[265,269] and some (like mercury, lead) are accumulative.
- Many detergents are toxic to marine life. They cause more damage than oil.[178]
- Pulp waste (sulfite liquor) cause decline of productivity of oyster bars[248], and affect young salmon.[252]
- Many marine animals and organisms are high concentrators of chemical elements and compounds.[248,284]
- Derivatives of plastic industry were found extensively distributed throughout Britain and Sweden in sea bird eggs.[269]

The sublethal effects of these toxic substances are not known yet.

K. Effect Due to Biocides[238]

Biocides consist of weedicides, herbicides, bactericides, fungicides, and pesticides, etc. They are one of the foremost pollutants and among the most dangerous.

Cause: Storm-sewer overflow, farmland runoff, direct application, and container disposal.

<u>Effect</u>: . Some persistent pesticides have been found in certain marine organisms.[270]

. Measurable concentration of pesticide residues have been found on estuarine and marine fish and sea birds feeding upon them.[269]

. 31 pesticides have been found in the eggs and larvae of the oyster and clam.[241]

. They are toxious on growth rate of oyster[237]. Insecticides have caused many fish kills in the U.S.[272]

. There are also damaging effects on marine plants.[231,259]

. DDT residues in sea birds can cause a declining of its breeding success.[195] Death of sea birds caused by effluent of pesticide factories was also reported.[269]

. The movement of ocean currents and the migration of birds and other animals make the effect far reaching. Residues of DDT and other organochloride pesticides used in the U.S. Antarctic bases are found in Antarctic seals and penguins far from the sources.

Most of the residue levels found in marine animals and birds are not lethal but there are still doubts as to what is a sublethal dose and what is the effect on breeding.

L. <u>Effect Due to Radioactive Materials</u>

a. Direct hazard comes from contacting with radioactive waste of high concentration.

b. Indirect hazard comes from the concentration of radioactive waste by organisms living in the sea and their subsequent use as human food.[282,283]

c. Ecological hazard of unpredicatable changes in biological communities in the ocean produced by long-lived radioisotopes. Estuaries are likely to receive and retain greater concentrations than the ocean. It has been found[284] that oysters, clams and scallops can contain concentrations of radioactive zinc over 100 thousand times that of surrounding water. The effect can be far reaching, for example, the radioactive cesium derived from atomic explosions was found in dangerous concentration in the tissue of Arctic caribou, thousands of miles from the area in origin.[270]

The true extent of this pollution and potential risks and damages that may result from it are not fully known.

M. Effect Due to Man's Activities[315,316,315]

Cause: From engineering work (such as diversion and damming of river water,[321] dredging and cutting waterways[314], shoreline construction[320]); and ocean floor mineral operation.

Effect:

- The change of salinity and modification of currents due to these activities will indirectly influence both predators and disease in ecosystem.[111]
- There will be considerable deleterious influence on the coral fauna and on fish population caused by large amounts of sediment churned up in the sea bed mineral operation.
- Sand and gravel dredging may have possible effect on ecology and topography.
- Sea bed blasting (from mining or military operations) will also exert damaging effect on the ocean community.[310]

V. CONTROL

5.1 Introduction

Effective control of pollution is based on the knowledge of the interrelations of ocean, marine life and the pollutant. The maintenance of "water quality" is of paramount importance.

The level of waste concentration in ocean depends on [308]:

- physical and chemical state of the waste
- initial mechanical dilution
- rate of diffusion
- the abundance and proximity of silt, sediments and marine populations
- location of release

5.2 Preventive Measure

A. Technical Aspects

a. Ocean study

The most uncertain factor in evaluating the problem of waste disposal into ocean is the lack of adequate knowledge of the currents, (Fig. 12-15), the natural temperature regimes, the diffusion, mixing and transport processes in the ocean. The aim of ocean study is to predict the temporal and spatial distribution of contaminants.

The general characteristics of the ocean waters are:[10,17,55]

- In inshore areas: There are more intensive mixing processes (Fig. 13). Each area is unique in its characteristics such as the evaporation, fresh water inflow, dilution by land water, and access to ocean. Certain general factors, such as the shallow depth, limited volume of water and low exchange of water, oppose dilution of any containment. The estuaries have been classified from their circulation pattern.[110,136,138] (Table 8 and Fig. 11)

. In the continental shelf: The region exhibits some of the characteristics of both inshore and deep ocean areas. The Coriolis force affects inshore current flow in this area as an outgrowth of the different densities created by land water runoff, and the outer portions are more affected by the currents of the deep sea. Turbulent mixing and turbidity currents are a special phenomena.

. In the deep sea: This is a much more constant and stable area. Temperature change and wind results mixing by convection and stirring. Circulation and vertical mixing are largely unmeasured. (Fig. 14).

1. Dilution in tidal estuary

The characteristics of an estuary and its relation with the sea to which it discharges have a considerable **bearing** on the movement of the wastes within the estuary itself and on the rate of interchange with the sea. Factors affecting the degree of dilution are[11,108,135-138,140] tidal action, density difference, wind action salinity intrusion, sedimentation rates, currents, coagulating and and flocculating effects of saline waters, configurations in the shores and bottoms of the estuaries.

The methods of analysis are:

. Tidal prism concepts

Assumption: The water brought into an estuary on the flood tide is completely mixed with the polluted estuarine waters, and the ebb flow consists of this mixed water.[134]

Drawback: There is no perfect mixing in the estuary due to stratification, stability and other factors.[107]

Modification: The segmentation method was proposed.[109,142] However, the improved method is still open to objection in regard to the assumption of complete vertical mixing in each segment.

. Concept of diffusion and mass-transfer

Assumption: Mass flux is proportional to the gradient of the mean concentration and that the flux is in the direction of decreasing concentration (analogy of Fick's law of diffusion).

The three-dimensional convertive-diffusion equation for turbulent incompressible flow becomes:

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + w\frac{\partial c}{\partial z} = \frac{\partial}{\partial x}\left(D_x\frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y\frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_z\frac{\partial c}{\partial z}\right)$$

where c is the time averaging concentration of diffusing substance, u, v, w are the velocity components in x, y, z direction, respectively, and D_x, D_y, D_z are diffusion coefficients due macroscopic turbulence of the fluid in the x, y, z space, respectively. In the pollution problem, the equation has to be modified with special consideration due to boundary variation and non-conservative substances. The diffusion coefficients are not the fluid properties. They represent the bulk properties of the flow. They are usually called longitudinal diffusion coefficients in shear flow.[154-156] They can be evaluated from salinity distribution analysis, theoretical considerations, and tracer experiments.[88,94] For the one-dimensional case there are two schools of thought[103]: the freshwater advection model,[124,139,151] and the tidal, time-varying advection model.[98,102]

2. Dilution in ocean[87,132,144,145,288]

There are two stages:

(i) Initial dilution[74,160,285]

Dilution takes place in the vicinity of the discharge point or line and is caused by jet action, and/or density difference. It is favored by strong density gradient, rapid jet velocity, high ratios of depth below the surface to the diameter of the jet. The spread will also be affected by the presence of stable thermocline layer. Multiple out ports of small diameter also favors the mixing process.[66,105,120,145,159]

The studies of mixing of turbulent jet are:

. on mechanism[67,113]

. on jet discharge into denser fluid[62,64,69,145,148]

. on jet discharge into a stable density gradient[73,75,96,121]

. on horizontal jet at free surface[45]

. on effect of angle of discharge[69,91]

(ii) Dispersion and transport

They are mainly affected by ocean currents (Fig. 12 - 15), wind waves[104], and are beyond engineering control. However, they are important factors in the selection of outfall site.[77] The mechanism of dispersal involves[71,136,154,155,164]:

. diffusion: molecular transfer is negligible compared with eddy diffusion

. convection: This is a dominant factor

Both can be expressed by Fick's Law.

The rate of dispersion depends on:

tidal and other currents, surface wind speed,[77,162] density gradient, direction of principal dispersion, volume of the containing water.

Experimental study has been conducted by methods of dye (fluorexcein, rhodamine B, pontacyl pink B, etc.), radio tracers, bacteria tracers, sea bed drifters and sea surface floats, and dredging on sediment transportation.

. the settling rate of particles.

b. <u>Marine life study</u>[7,8,19,38]

The study includes the biology of pollution[37,39], the relation with estuarine processes[47-49], the relationship of algae and other organisms to marine pollution.[30,44,275]

c. <u>Criteria of water quality</u>[32,42,50,61,130,132,263]

The purpose is to provide physical, chemical and biological standards for pollution monitoring and control.

Parameters of marine pollution are:

. <u>physical</u>: radioactivity, salinity, temperature, turbidity and color, settleable solids and floating materials, odor.

. <u>chemical</u>: DO, BOD, petroleum products, toxic substances, tainting substances, nutrients, nuisance organisms.

. <u>biological</u>: coliform organisms,[61,130,227,235,236,249], fish catches, plankton species.

The present criteria are:

<u>on oil</u>: The present trend of 100 parts per million of oil in sea water as maximum concentration that may be dumped overboard is still high because of the heavy sea traffic.[219]

<u>on radioactive effluent</u>: The U.S. AEC standard treats each reactor as an isolated entity. The limit is criticized as too lax.[307]

<u>on coliform concentration</u>:[227,236] The criteria of coliform concentration on bathing waters is not settled yet. In California it is limited to 10 per milliliter, and not to be exceeded in more than 20 percent of the samples at a given location within a specified period of time.[263]

The needs in this area are:

- developing of temperature and biological criteria for the receiving waters
- developing the most informative danger signals for marine pollution
- establishing optimum sampling procedures
- reviewing and analyzing criteria for bathing water.

d. Waste treatment

The program consists of treatment processes, non-treatment methods of pollution control, ultimate disposal and recycling of wastes.

1. Natural purification

Fully aerated water oxygen content is about 10 ppm at 14°C. However, BOD of sewage is about 30-50 times this amount. Some form of pre-treatment for all noxious and poisonous effluents should be done before discharge to marine waters.

2. Sewage and industrial waste:

Many industrial wastes differ markedly in chemical composition and toxicity from domestic sewage. They often contain persistent or refractory organics which resist secondary treatment procedures that are normally applied to domestic sewage. The sewage digestion tank developed for space vehicles can be used for ship board use in order to reduce overboard waste dumping.

There is a need for improved methods of treatment for industrial wastes.

3. Oil waste

The needs are:

- developing of facilities for the receiving and treatment of oily waste mixtures.
- adopting of load on top practice for tankers.

4. Thermal waste

The present treatments are cooling ponds, cooling tower (not economical) and direct discharge into receiving water. The needs for new methods of cooling and the development of beneficial use are urgent.

5. Radioactive wastes[301]

They are not susceptible to biological or oxidative treatment. The general methods of treatment are:

filtration, evaporation, ion exchange, gas stripping, chemical precipitation, coagulation, incineration and dilution.

The present disposal approaches are:

- concentration and containment:

  The procedures are treatment, storage, container (steel and concrete[275]), transportation and handling equipment for dumping.
- dilution and dispersal

The major concerns in nuclear waste disposal are:

- possibility of the return of radioactivity to man
- possibility of severely altering the biological balance of the ocean

. interference with other uses of the sea.

The dumping practice:

Dumping in deep trenches are not recommended[301]. The present design for waste containers is for ten years life expectancy[308]. They are exposed to the danger of being burst out due to the terrific pressure and the buffeting by currents, and moved to an unintended place. The full knowledge of these damaging factors are lacking.

e. Outfall design[119,132,160,262,273]

The principle is to make the effluent to enter the ocean in a manner that will lead to the most effective dispersion of the wastes.

Factors affecting the design of outfalls are given by Peason[51] (Table 9). The performance of outfall can be evaluated by coliform counts[92], fish trawl study[79], and dye tracer test.[119]

f. Improved ship design and navigation system

The current trends for ship design are:

. size is increasing

. tanker speed is essentially unchanged

. speed of dry cargo and special products carriers is increased (15-20 knots)

. greater drafts

. simplification in machinery design and handling systems

The potential danger will be:

. large quantity of potential cargo release

. less probability of ship survival in the event of collision and stranding

. less flexibility in control of cargo.

The needs for improved ship design are:

. consideration of pollution prevention measures in ship design

. feasibility of adding protective features to existing fleets

The needs in navigation systems are:

. adequately trained crews

. feasibility of shore-based guidance system.

. study of ship traffic pattern and establishing sea lane navigation system.

g. Surveillance

1. Water quality monitoring system

The needs are:

. developing methods of detection and surveillance of pollution. In 1967 the U.S. Coast Guard reported 458 detected violations of oil pollution statutes. Many others were not reported because of difficulty in detection. The actual violations may be closer to 5,000.[14]

. developing methods of tagging pollutants

. developing in site monitoring devices.

2. Safety procedures in harbors[14,216,219]

Current needs are:

. radio broadcasts of navigation information and marine traffic activities

. establishing information on hazardous cargoes such as their movement, cargo properties and emergency control methods.

. survey of coast area

. study of traffic flow and charting

. improvement of handling and storage of the dangerous cargoes

3. Safety on the continental shelf[14]

The needs are:

- review design practices of offshore ports to accommodation of supertankers.
- study of transfer facilities, such as pipelines, artificial islands, isolated shore locations, ship to barge transfer, ocean barge systems, and submarine tankers.
- minimizing conflicts among the various activities including shipping, transfer of liquid or gases in pipelines, fishing, recreation, drilling, pumping and storing materials underwater or at the surface.
- elimination of wrecks, debris and litter.

h. System management[319]

The program is a systematic cleanup toward entire river basins. The principle is that engineering changes should always be preceded by thorough consideration of all the physical, chemical and biological results to be effected[161]. The influencing factors are:

- waste load
- upstream water development[321]
- engineering structures and dredging[138]

The management consists of:

- choices of management objectives[318]
- multiple usage[320]
- proper use of marsh management techniques to protect coastal ecologies

. imaginative and constructive approaches to new potential[49]

The integrated approach of many fields is the main theme of the program.

B. Industrial Aspects

The active role played by the industry is essential to pollution control.

Current needs are:

. reducing overboard discharge of waste

. adopting load-on-top practice in tankers

. establishing safe standards on waste effluent

. providing safety standards for offshore activities.

C. Legal Aspects

Pollution of the sea is both a national and an international problem for all coastal countries. Pollution respects no national boundaries. The enforcement of laws and regulations should be based on the realistic water quality criteria and practical detecting equipments.

a. National

The territorial limit in U. S. for states is 3 miles of off-shore ocean waters, and 12 miles for the nation. Some important laws are:

. 1924 Oil Pollution Act (33 USC 431 et seq.). The Act makes illegal grossly negligent or willful discharge of oil into the sea from vessels.

. 1899 The Refuse Act (33 USC 407 et seq.) also cited as the Rivers and Harbors Acts

. The Federal Water Pollution Control Act (33 USC 466 et seq.)

. The Outer Continental Shelf Land Act (43 USC 1331-1343)

. Act to authorize Federal assistance to state and local governments in major disaster and for other purposes (42 USC 1855 et seq.)

. 1961 U.S. Oil Pollution Act (33 USC 1001 et seq.) prohibiting waters of oil discharge and requiring for logging of oil discharge

. 1966 Clean Water Restoration Act

. 1970 H.R. 4148 Water Quality Improvement Act, prohibiting the discharge of oil into waters off the U.S. out to 12 miles and impose civil liability up to $100 per gross registered ton, or a maximum of $14 million per spill.

b. International

. 1909 U.S. and Great Britain, The Boundary Waters Treaty (Great Lakes and St. Lawrence Seaway).

. 1958 Convention on the Territorial Sea and the Contiguous Zone (control over nine mile zone, contiguous to its three mile territorial sea)

. 1962 International Convention for the Prevention of Pollution of the Sea by Oil (Convention at 1954)

. 1969 Intergovernmental Maritime Consultative Organization Convention on Oil Pollution

. 1969 Britain and eight other countries, North Sea Pact.

5.3 Cleanup Operations

In general it involves source control, containment, environmental protection, pollutant recovery or neutralization, restoration of damaged resources, disposal of recovered materials.

A. Oil Cleanup

a. Contingency plan

Effective control of damage depends on well prepared plans and fast delivery of control equipments. It requires both local and national efforts.

b. Survey and prediction of slick behavior

Very little information is available in this area. It is difficult to predict the behavior of oil slick due to the presence of a great number of time dependent variables.

Oil Spreading

1. Affecting Factors:

Physical forces[187]:

- Force of gravity
- Surface tension force
- Water surface motions caused by waves, wind (at about 2-4 percent wind velocity) and tidal currents (random motion)
- Moving stream (ocean currents)
- Coriolis force
- Inertia force
- Viscous force

Oil properties:

- such as density, viscosity, surface and interfacial tension, emulsification with sea water.

2. Spreading stages

- The beginning phase: Gravity and inertia forces are important
- Intermediate phase: Gravity and viscous forces dominate

. Final phase: Surface tension is balanced by viscous force. Based on these mechanisms, Fay[187] gave an order of magnitude estimation on oil spreading rate and compared with limited experimental data.[217,220]

3. <u>Observations</u>[166,171,172,220]

The oil first spread rapidly to a size which increases with volume of the spill, then followed by a long period of no further growth. This was probably due to the sudden reduction of the net surface tension at a time when evaporation and dissolving of the lighter components of the oil has occurred.[187]

In the Santa Barbara oil spill the effect of wind and current on the oil spreading was observed.[166] The effect of tidal action and effect of higher seas and greater depth on spreading was also reported in the Torrey Canyon spill.[180] It was observed that oil can spread to 1/100th of an inch over 25 square miles in eight hours.[185]

4. <u>Oil conditions in the sea</u>

It involves processes of spreading, oxidation by bacteria, evaporating of volatile ingradients, and the final congealation into lumps.[179,226]

<u>Measurement and tagging of oil spill</u>

Correct measurement and tagging of oil spill is essential to both legal and technical aspects. The developing and refining of aerial photography, methods of infrared imagery detection[176,186,197,200,212] are needed.

c. Source control

It is mainly the salvage operation on the vessel and/or the cargo. Present technique is inadequate. Some needs are:

- the development of equipment and procedure of salvaging distressed tankers, such as the dropping of inflatable storage bladders into which oil can be pumped from the tanker.
- the development of techniques for aerial deployment and on site delivery of equipment.

d. Physical cleanup operations

The selection of proper methods and equipment depends on its effectiveness criteria[169], such as

- completeness of removal of spilled materials
- speed of application
- effect on pollution or hazard
- applicability to limited access areas
- sensitivity to natural phenomena
- toxicity to marine life
- availability

1. Containment

Booms: effective only for calm sea (sea state under 3) and in harbor area.

Types:

- Solid material: most portable and effective so far.
- Underwater bubble barriers: under development, good for quiescent water.
- Chemical booms: under development

<u>Problems</u>: For current larger than about 1-1/2 - 2 knots there is difficulty in anchoring or mooring.[198]

2. Absorbent

<u>Types are</u>:

. straw, sawdust: all around method

. plastic or other polymeric materials: such as polyurethane foam; oil can be recovered

. gelling agents: They can solidify petroleum materials

. skimmer boat: good for calm sea, oil can be recovered

. sinking materials: such as sand, cement, etc., good for deep ocean with large oil spill.

3. Retrieval

<u>Methods are</u>:

. manual

. surface suction devices

. rotating drums and scubber belt

. skimmers

<u>Problem</u>: There is a need for developing improved recovery system.

4. Chemical dispersion[183,189,210]

<u>Types are</u>:

. detergents: All are toxic to aquatic life[178,191]. They are not recommended in estuary use. Detergents are effective for cleaning rocks and sea walls.

. oxidation and biodegradation[226]: The effectiveness is controlled by many environmental conditions. The rate of cleaning is slow. Artificial seeding of microorganisms which feed on oil is under study.

Since most chemical dispersion agents have toxic effect, it is preferred to use methods of physical collection whenever possible.

5. Burning

This can be used for source control when all attempts to salvage the vessel or cargo fail. The method is not effective on surface oil due to rapid heat transfer.

6. Treatment and disposal of recovered slicks

The controlling factors are economics and environmental disposal standards. Oil reclamation from recovered slicks has not been exploited. There is also a need for developing better port facilities to receive and treat the oily mixtures

e. Restoration

The methods depend on site condition Mechanical removal is preferred where possible.

Beaches

. physical removal of the contaminated materials (best with absorbents).

. plowing under and covering with uncontaminated sand.

. detergent cleaning in combination with mechanical tilling (expensive, toxic, inefficient)

. a combination of the above methods

Rocky coast, seawalls and structures

Steam cleaning with detergents is good.

Waterfowl

So far all attempts are futile.

Current needs in restoration process are:

- improved methods and procedures to protect central area and shoreline.
- developing effective techniques for the rescue and rehabilitation of waterfowl and other wildlife.
- study of the behavior, with time, of various types of crude oil and refined products on beaches

B. Cleanup of Other Types of Pollution

The general principles are similar. However, special methods are required to cope with each unique problems.

IV. AREAS OF RESEARCH NEED

The solution to ocean pollution requires a multi-disciplined effort from all professions. Some urgent needs have been pointed out under different subjects in the text. The author would like to emphasize certain research areas which are of special interest.

Legal Aspect:

- Need for laws and regulations on oil discharges from shore installations and offshore drilling operations

Ocean Study:

- Refinement of physical model and controlled laboratory studies.
- Investigation on the interchange of deep sea water with that near the surface and the extent, if exist.
- Study on the air-sea interactions, such as the degree of mixing due to wind generated waves on the sea surface; the correlation of mean wind velocity at the surface and the mean velocity of the ocean current.
- Study on the movement of ocean water, especially the submarine currents
- Improving oceanographic research on coastal constructions.
- Basic research to identify the significant estuarine processes and their quantity relationship.
- Study on the transport and behavior of heat in sea water, such as the degree and extent of affected reaches; the time required to reach equilibrium conditions after the heated water is discharged; the method of predicating water temperature, the distribution of heated water in stratified fluids, and the effect of temperature on sediment transportation

- Study the processes of diffusion, mixing and transport, especially that due to strong ocean rivers, of radioactive nuclides.
- Gathering and interpreting geophysical data on offshores, with special attention on the sea bed structure.

Effect of Pollution:

- Laboratory study on sublethal or long-time effects of all pollutants on marine organisms.
- Investigation on the behavior of aquatic food chain in both fresh and salt water bodies, with special attention to the study of routes of radioactivity from waste to man.
- Study on the relationship between temperature distribution and the DO concentration of the water.

Pollution Control

Control of source:

- Study on the feasibility of developing method of acoustic detection on the degree of rock penetration of a stranded vessel.
- Developing means for speedy transfer of the cargo from a stranded tanker.

On thermal pollution:

- Improvement on methods of cooling by mechanical and natural draft.
- Developing beneficial use of waste heat.

On waste dumping:

- The design of waste container for deep sea dumping
- Study on the possible damaging factors of such containers, and, if broken, the escape rate, diffusion rate of the waste and their effect on sea life.

On industrial wastes:

. Method of recycling all wastes.

On oil pollution:

. The study of hydrodynamic and aerodynamic forces on boom in order to develop the critical design criteria.

. Investigation on the effect of natural factors on the movement, dispersal and destruction of oil at sea.

. Development of oil-water separation devices.

. Development of method and equipment of oil detection and measurement.

. Study on the effective burning technology of oil on the sea surface.

. Developing means of controlling waste oil from service stations and other sources from flowing into municipal sewers and waterways

On outfall effluent:

. Survey of the current disposal system

. Study the effect of a stable thermocline layer on the mixing process of outfall discharge.

. Assess the influence of such environmental factors as wind, current, temperature, density stratification, sunlight, and source size on the rate of dilution and disappearance of a nonconservative constituent of waste water.

On safety operations:

. Survey, evaluating, and developing effective monitoring equipment and methodology on water quality and mixung conditions near outfall.

. A feasibility study of shore guidance system for the sea traffic control.

On offshore operations:

- Critical review on the offport transferring methods.
- Study on the safety of pipeline design and construction.
- Study on the shock wave effect on fisheries and other marine life from under water detonation in mining operations and other construction activities.

On system management:

- Study on the optimum, long range multiple use of water in the whole river basin system

VII. CONCLUSION

- The Ocean is man's last frontier, and the very source of the world's livelihood. There has been an increasing tendency of man's dependence on the ocean. (Fig. 3.4, and Table 1.2).
- However, it has long been regarded as a "no-man's land", the resources of which anyone is free to use and damage without restraint. The evidence of adverse effects of pollution is mounting. The indirect sublethal biological and ecological effects on marine life, and man himself may be difficult to detect or predict at the present time, but nevertheless is of great consequence in the long run.
- For many materials, the ocean is indeed an effective and safe sink which may even benefit from wastes introduced in the right place, at the right time, and in the right amount. Current information, technology, and institutions are inadequate to deal with the ocean pollution problems.
- Water quality should be the denominator for multiple use of the ocean water. The control of marine water pollution is a governmental, industrial, and technical problem. It requires multidisciplinary effort among many professions. Some urgent research areas have been identified.
- Man had demonstrated his technological ability by sending man over to the moon and bringing him back across a quarter million miles in space. He can surely be able to deal with any problems on the ocean of his own planet, if he wants to. The grave situation of ocean pollution deserves immediate attention before it is too late.

VIII TERMINOLOGY

Abyssal plain: Large area of ocean bottom which receives major portions of of marine sediments, characterized by extreme flatness and gentle slope less than five feet per mile.

Acid mine drainage: Drainage from certain mines, especially coal mines, containing acidic salts in solution. It is formed primarily by air oxidation of iron pyrites in the presence of moisture.

Activated sludge: Sludge floc produced in raw or settled waste water by the growth of zoogleal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed.

Activation: the generation, under aerobic conditions, of organisms capable of absorbing organic material from the water in the activated sludge process.

Aeration: the bringing about of intimate contact between air and a liquid by one or more of the following methods:
(a) spraying the liquid in the air
(b) bubbling air through the liquid
(c) agitating the liquid to promote surface absorption of air.

Aerobic: Requiring, or not destroyed by, the presence of free elemental oxygen.

Aerobic bacteria: Bacteria that require free elemental oxygen for their growth

Aerobic digestion: Digestion of suspended organic matter by means of aeration.

Aerochlorination: the application of compressed air and chlorine gas to waste water for the removal of grease.

Algae: Primitive plants, one- or many-celled, usually aquatic, and capable of elaborating their foodstuffs by photosynthesis.

Algal bloom: Large masses of microscopic and macroscopic plant life, such as green algae, occurring in bodies of water.

Benthos: (1) the fauna and flora of the sea bottom
(2) aggregrate of organisms living on or at the bottom of a body of water.

Benthic organisms: Lives on the bottom of the ocean. These include those which are fixed in place and cannot move, such as oysters and barnacles and those which can move about, such as starfish, lobsters and crabs.

B. Coli: A member of the coliform group now classified as E. Coli.

Bioassay: Determination of the relative effective strength of a substance by comparing its effect on a test organism with that of a standard preparation.

Biochemical oxidation: an oxidation brought about by biological activity which results in chemical combination of oxygen with organic matter.

Biochemical oxygen demand (BOD): A standard test used in assessing waste water strength.

Biochemical process: The process by which the life activities of bacteria and other microorganisms in the search for food, break down complex organic materials into simple, more stable substances.

Biocides: Chemical compounds that destroy life, such as: weedicides, herbicides, bactercides, fungicides and pesticides. Great many developments of compounds which could be used to interfere with life processes in specific target species.

Biodegradation: The destruction or mineralization of either natural or synthetic organic materials by the microorganisms populating soils, natural bodies of water, or waste water treatment systems.

Biological oxidation: The process whereby living organisms in the presence of oxygen convert the organic matter contained in waste water into a more stable or mineral form.

Biological process: (1) the process by which the life activities of bacteria and other microorganisms, in the search for food, break down complex organic materials into simple, more stable substances. (2) process involving living organisms and their life activities Also called biochemical process.

Biological purification: the process whereby living organisms convert the organic matter contained in waste water into a more stable or a mineral form.

Biosphere: the totality of things living in, on, or above the earth's crust. In a broad sense, the biosphere extends as far into the cosmos as do space probes containing biota.

Biota: the animal and plant life of a region; flora and fauna collectively.

BOD: (1) abbreviation for biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. (2) A standard test used in assessing waste water strength.

BOD load: the BOD content, usually expressed in pounds per unit of time, of waste water passing into a waste treatment system or to a body of water.

Boom: A floating structure used to protect the face of other structures built on water from damage by wave action or by floating material being dashed against it by the waves, or to deflect floating material away from it.

Brackish water: Water in which salinity values range from approximately 0.50 to 17.00 parts per thousand (mineral content between fresh water and sea-water).

Chocolate mousse: Spongy, sloppy oil in water emulsion (up to 70 percent water) either produced by detergent or by wave action.

Coastal waters: waters affected by the ebb and flow of the tides, including estuaries.

COD (Chemical oxygen demand): A measure of the oxygen consuming capacity of inorganic and organic matter present in water or waste water. Expressed as the amount of oxygen consumed from a chemical oxident in a special test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with BOD. Also known as OC (oxygen consumed) or DOC (dischromate oxygen consumed).

Coliform-group bacteria: A group of bacteria predominantly inhabiting the intestines of man or animal, but also occasionally found elsewhere.

Contamination: Any introduction into water of microorganisms, chemicals, waste, or waste water in a concentration that makes the water unfit for its intended use.

Continental deposits: Deposits laid down on land by rivers, winds, glaciers, etc., in contrast to deposits laid down in the ocean.

Continental Rise: A gently sloping, submerged surface lying to seaward of the base of the continental slope. An abyssal plain usually lies seaward of the continental rise.

Continental shelf: The zone surrounding continental blocks extending from the low water line to the depth at which a marked increase of slope to greater depth occurs.

Continental slopes: The declivity from the outer edge of the continental shelf or continental borderland into great depths.

Current rose: A graphical representation of currents, usually by quadrangles, using arrows for the cardinal and intercardinal compass points, to show the resulting drift and frequency of set for a given period of time.

Curie: The basic unit intensity of radioactivity in a sample of material. One Curie equals 37 billion disintegrations per second, or approximately the radioactivity of 1 g of radium.

Deep-sea deposit: A deposit in the bed of the ocean made in water of a depth of about 100 fathoms (600 ft.) or more.

Deoxygenation: To remove oxygen from waste water or sewage.

Diatom: Microscopic, single-celled plant growing in marine or fresh water.

Diffusion: The transport associated with molecular action and with turbulent action, or the transport in a given direction at a point in the flow due to the difference between the true convection in that direction and the time average of the convection in that direction.

Dilution: Disposal of waste water or treated effluent by discharging it into a body of water.

Digested sludge: Sludge digested under either aerobic or anaerobic conditions until the volatile content has been reduced to the point at which the solids are relatively non-putrescrible and inoffensive.

Dispersion: The transport associated with the variation of the velocity across the flow section, or the transport in a given direction due to the difference between the true convection in that direction and the spatial average of the convection in that direction.

Dissolved oxygen (DO): The oxygen dissolved in water, waste water, or other liquid, usually expressed in milligrams per liter, parts per million or percent of saturation.

Diurnal: The tides and tidal currents are said to be diurnal when a single flood and single ebb occur each lunar day (24.84 solar hours).

Drift: Speed of current flow.

Ecology: Study of the relationship between organisms and their environment.

Ecosystem: Consisting of all living members of a biological community and all the non-living factors affecting them.

Emulsion: A heterogeneous liquid mixture of two or more liquids not normally dissolved in one another, but held in suspension one in the other by forceful agitation or by emulsifiers which modify the surface tension of the droplets to prevent coalescence.

Enthalpy pollution: Any anthalpy modification of a stream which produces a temperature profile different from the theoretical or optimal one.

Enthalpy purification: Any man-made alteration in the abnormal or suboptimal temperature profile in the direction of the optimal state, defined by the optimal temperature profile.

Estuary: An embayment where river water mixes with and measurably dilutes sea water, the head of which is usually considered as the limit of salt water intrusion.

Estuarine zone: An environmental system consisting of an estuary and those transitional areas which are consistently influenced or affected by water from an estuary such as, but not limited to, salt marshes, coastal and inlet-tidal areas, bays, harbors, lagoons, inshore waters and channel. (U.S. Congress, Clear Water Restoration Act 1960).

Euthrophic: Relating to or being in a well-nourished condition.

Eutrophication: The process of becoming more eutrophic either as a natural phase in the maturation of a body of water or artifically (as by fertilization).

Fetch: The effective distance, in one direction, over which the wind acts on the water surface.

Flood currents: Current associated with an increase in the height of a tide. They generally set in the same direction as the tidal progression and perpendicular to the cotidal lines.

Flushing time: The time taken for a unit in-flow of fresh water to reach the sea.

Forel scale: The basic scale for describing water color. Consisting of vials of water in closely varying shades of yellow-green-blue, against which are compared the sea water sample.

Foreshore: Portion of the shore or beach lying between the low-water mark and the upper limit of normal wave action.

Fouling: The assemblage of marine organisms that attach to and grow upon underwater objects.

Gulf stream: Formed of several equatorial currents that merge in the straits off Florida, extending to the Grand Banks off Newfoundland; it gradually loses its identity continuing as the broad, slow-moving North Atlantic Current.

Gyral: Swirling system of clockwise and counterclockwise flowing sea currents, the combined results of winds, earth's rotation, gravity, and other forces.

Half-life: The time in which half the atoms in a radioactive substance disintegrate. It varies from millionths of a second to billions of years.

Hazardous substance: Matter of any description or origin other than oil, which when discharged into any waters in substantial quantities, presents an imminent and substantial hazard to the public health or welfare, including fish, shellfish, and wildlife and shorelines and beaches.

Higher-high water (HHW): The higher of the two high waters of any tidal day or the single high water when a semidiurnal tide becomes diurnal.

Higher-low water (HLW): The higher of the two low waters of any tidal day.

High water: The maximum height reached by a tide. The height may be due solely to the periodic tidal force or it may have superimposed upon it the effects of meteorological conditions.

Industrial photosynthesis: Term describing the controlled growth of complex populations of microorganisms, principally unicellular green algae. Combined into systems of waste water management, it is capable of:
(1) Purifying waste water
(2) Providing reclaimed water
(3) Producing high-protein animal feed
The System operation requires minimum temperature and high light intensities.

Inshore: The region shoreward of a certain depth of water, usually either the 3- or 5-fathom isobath.

Inshore currents: The movement of water inside the surf zone, including long shore and rip current.

Inshore water: Water contiguous to land in which the physical properties are considerably incluenced by continental conditions.

Intertidal zone: Generally considered to be the zone between mean high water and mean low water level.

Isobaths: Lines connecting points of equal depth.

Isohaline: Line drawn through points representing equal salinity.

Isotopes: Atoms with the same atomic number (same chemical element), but different atomic weights. Atoms of which the nuclei have the same number of protons but different numbers of neutrons.

Kelp: Brown algae of the order Laminariales, including the largest known algae. Kelp typically grow on rock or stone bottoms. They attain their greatest size in cold waters, with lengths as great as one hundred feet and blades four or more feet in width.

Limnology: Scientific study of bodies of fresh waters, as lakes or ponds, or streams, with reference to their physical, geographical, biological and other features.

Littoral current: A current that moves along the shore in a direction parallel to the shore line.

Littoral zone: The marine environment influenced by a land mass. The coastal region.

Load on top: When a tanker is operating the LOT system the oil from the tank washings is retained on board, the free water below being drained off, and is ultimately released almost always to a refinery instead of being discharged into the sea.

Longshore currents: Currents moving within the surf zone parallel to the shoreline. Generated by waves breaking at an engle to the shoreline.

Low water (LW): The minimum height reached by a tide. The height may be due solely to the periodic tidal force, as it may have superimposed upon it the effects of meteorological conditions.

Marginal trench: A deep f rrow which parallels the trend of the continental margin between the base of the continental slope and abyssal plain. Marginal trenches usually are about one thousand fathoms deeper than the general level of the adjacent ocean floor. The Puerto Rico trench north of Puerto Rico is one of the few trenches found in the North or South Atlantic Oceans, whereas trenches are common in the Pacific Ocean.

Mean high water (MHW): The average height of the high waters over a 19-year period.

Mean low water (MLW): The average height of the low waters over a 19-year period.

Mean tide level: The average of the high waters and the low waters over a 19-year period.

Mid-Ocean canyon: Steep-walled, flat-floored, continuous depression up to five miles wide and six hundred feet deep that traverses an abyssal plain; such canyons are thought to have been formed from turbidity current erosion.

Mid-ocean ridge: A 40,000 mile long, continuous median mountain range identified in the Arctic, North Atlantic, South Atlantic, and Indian Oceans. Crest of the ridge is usually found at 500 to 1,300 fathoms beneath the sea surface. The base is usually a few hundred miles wide, and has a relief of 10,000 to 33,000 feet.

Mid-ocean rift: A deep, narrow notched, cleft valley, or graben, found to exist almost continuously along the crest of the mid-ocean ridge. The rift is generally 15 to 30 miles wide; its base is usually 700 to 2100 fathoms below the sea surface.

Molluscs (Mollusks): Marine animals (Usually with shells) significant as fouling forms, including mussels, jingles shells, oysters, and boring forms, such as shipworms and boring clams.

Mussels: Marine, brackish, or fresh water molluscs; sometimes called clams.

Nodules: Lumps of manganese, cobalt, iron, and nickel found in various regions on the ocean floor.

Nontidal currents: Includes the permanent currents in the general circulatory systems of the sea as well as temporary currents arising from winds.

Offshore: Converse of inshore.

Offshore currents: Nontidal currents outside the surf zone, which are not affected by shoaling and river discharge.

Offshore water: Water adjacent to land in which the physical properties are slightly influenced by continental conditions.

Outfall: The point, location, or structure where waste water or drainage discharges from a sewer, drain, or other conduit.

Ocean pollutant: An additive that changes the quality of the water so as to interfere with its use for some desired purposes.

Oxygen depletion: Loss of dissolved oxygen from water or waste water resulting from biochemical or chemical action.

Persistent pesticides: Pesticides having cumulative effect in living creatures such as DDT, chlorinated hydrocarbon compounds, dieldrin, endrin, etc.

Pelagic organisms: Those which float on the surface or in the water, such as jelly fish and some forms of plankton, and those organisms that can swim or otherwise move themselves about, such as fish and shrimp.

Photosynthesis: The synthesis of complex organic materials, especially carbohydrates, from carbon dioxide, water, and inorganic salts, with sunlight as the source of energy and with the aid of a catalyst such as chlorophyll.

Phytoplankton and zooplankton: Lower forms of sea life (passively floating plants and animals). They are in the food chain, usually concentrators (uptake of many radioactive isotopes due to their affinity for these elements.) Phytoplankton produces about one fifth of the earth's oxygen.

Plankton: All the drifting and floating life of the sea. Made up of microscopic or relatively small plants and animals, which travel with the water movements. Many of the organisms can swim, but their locomotion is weak and ineffective.

Pollutional index: A criterion by which the degree of pollution of body of water may be measured, such as bacterial density, plankton, benthos, biochemical oxygen demand, dissolved oxygen, or other index of water quality.

Plankton bloom: The rapid growth and multiplication of plankton (usually plant forms) producing an obvious change in the physical appearance of the sea surface, such as coloration or slicks; also called sea bloom and florescence.

Pollutants: A polluting substance, medium or agent; waste products from industry or in sewage.

Pollutional load: The quantity of material carried in a body of water that exerts a detrimental effect on some subsequent use of that water.

Pollution incident: A discharge of oil or other hazardous substance of such magnitude or significance as to require immediate response to contain, cleanup or dispose of the material to prevent a substantial threat to public health or welfare.

Prevailing currents: The predominant or usual movement of water.

Pulp waste: Wastes from plants that process wood into cellulose product by various processes.

Primary waste treatment: Including screening, settling and intermittent chlorination.

Radiation concentration guide: The amount of any specific radioisotope that is acceptable in air and/or water for continuous consumption. It is equivalent to what was formerly called the maximum permissible concentration (MPC).

Radioactivity decay: The spontaneous radioactive transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. Every decay process has a definite half-life. In the process, the nuclei seek a more stable arrangement by release of energy in the form of radiation such as alpha, beta, gamma rays.

Radioisotopes: Radioactive isotopes of an atom, usually artifically produced.

Raw sludge: Settled sludge promptly removed from sedimentation tanks before decomposition has much advanced. (undigested sludge).

Red Tide (Gymnodinium brevis): A microscopic form of sea life, which under certain conditions, triggers the notorious fish killer "red tide". (Mass of genyanlax, a marine organism which feeds on organic wastes, depletes the waters of dissolved oxygen, has harmful effect to other marine life.)

Rip currents: narrow seaward moving water currents which return to deep water carried landward by waves. Rip currents are believed to be almost universally associated with large breakers on an exposed coast.

Salinity: The relative concentration of salts, usually sodium chloride, in a given water, usually expressed in terms of the number of parts per million of chlorine.

Sea bloom: See plankton bloom.

Sea grass: Seed-bearing marine plants, more highly organized than algae, found in shallow waters both brackish and marine, attaining lengths up to 8 feet.

Sea slick: An area of sea surface, variable in size and markedly different in appearance (color and oiliness) usually caused by plankton blooms.

Sea state: Numerical or written description of ocean surface roughness.

Septic sludge: Sludge from a septic tank, or partially digested sludge from an Imhoff tank or sludge-digestion tank.

Shoaling effect: Alternation of a wave proceeding from deep water into shallow water.

Shore current: A current set up in the water adjacent to the shoreline. Usually caused by the waves striking the shoreline at an oblique angle.

Slop oil: Oily waste from ballast tank cleaning operation.

Sludge: The accumulated solids separated from liquids such as water, during processing, or deposits on bottoms of bodies of water.

Sludge digestion: The process by which organic or volatile matter in sludge is gasified, liquified, mineralized, or converted into more stable organic matter through the activities or either anaerobic or aerobic organisms.

Sludge treatment: The processing of treating waste water sludges to render them innocuous. This may be done by aerobic or anaerobic digestion followed by drying on sand beds, filtering and incineration, filtering and drying or wet air oxidation.

Spoil (dredge spoil): Dug-up earth sludge combination from bottom of water bodies to improve navigation.

Standard biochemical oxygen demand: Biochemical oxygen demand as determined under standard laboratory procedure for 5 days at 20°C, usually expressed in milligrams per liter.

Swell: Ocean waves which have advanced beyond the area of their generation.

Subsurface currents: Currents flowing below the surface current. These currents normally flow at a different speed than the surface currents and may have a different set.

<u>Storm-water overflow system</u>: Designed to drain sanitary sewage in combined systems and large quantities of storm water drainage in separate systems into the estuarine areas during times of high rainfall.

<u>Thermal pollution</u>: Effect of unnatural increase or decrease of water temperature caused by the industrial use of water.

<u>The desert of the ocean</u>: In the warmer parts of the open ocean where mixing between the surface water and the nutrient rich deep layers is restricted, fertilizers (nitrates and phosphates) are scarce in the sunlit surface layers.

<u>Tidal basin</u>: A dock, basin or bay connected with an ocean or tidal estuary in which the water level changes with fluctuations of the tides.

<u>Tidal current cycle</u>: The complete oscillation of the flood and ebb through all phases of the tide from high water to the next succeeding high water. The duration of a semidiurnal tide approximates 12.42 hours, while that of a diurnal tidal approximates 24.84 hours.

<u>Tidal currents</u>: Currents caused by the horizontal movement of tides.

<u>Tidal inlet</u>: A transverse channel through a barrier bar or beach that permits seawater to sweep in and out of a lagoon.

<u>Tidal prism</u>: The volume of water required on the flooding tide to produce the rise of water level in a bay, estuary, etc.

<u>Tidal river</u>: A river in which flow and water surface elevation are affected by the tides. In some streams, the effect may extend a hundred or more miles upstream from the mouth.

<u>Total ecology</u>: The interrelationship between all parts of the marine biological system.

<u>Trade wastes</u>: Wastes from factories and gas works such as cyanides, toxic metals, phenols, and other chemical compounds; most are highly toxic to marine organisms.

<u>Turbidity current</u>: A rapid, large volume down slope movement of sediment from the continental slope. Usually triggered by an earthquake with its epicenter at or near the continental slope, by excessive sediment deposition on a portion of the slope, which gives way under the added weight, or through slope disturbance by seismic sea waves.

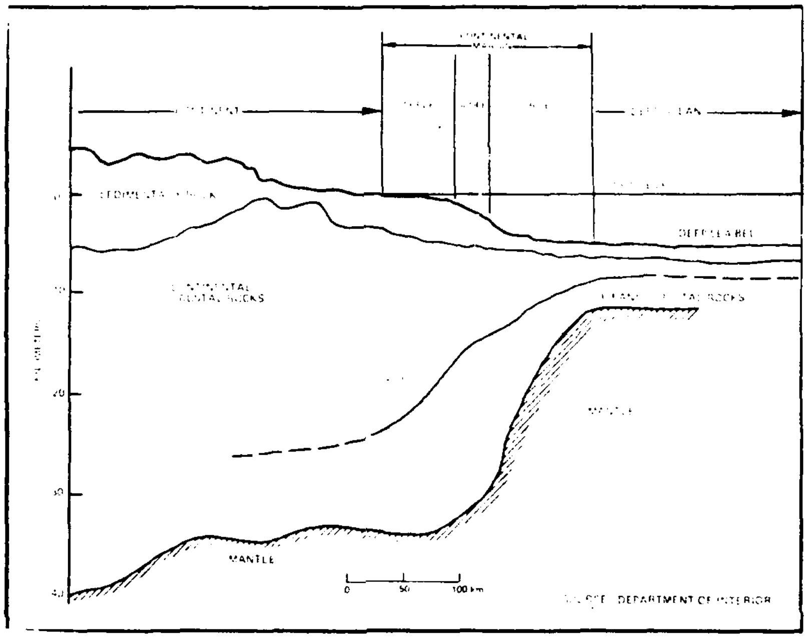
<u>Ultimate biochemical oxygen demand</u>: The total quantity of oxygen required to satisfy completely the first stage biochemical oxygen demand.

<u>Uprush</u>: The rush of water onto the foreshore following the breaking of a wave.

<u>Upwelling</u>: An upward movement of subsurface water generally caused by winds moving coastal surface water offshore, or by diverging surface currents.

<u>Zooplankton</u>: The portion of plankton composed of animals. Unattached animals which are at the mercy of the currents.

Figure 1. Generalized Geological Cross Section of Continental Margin



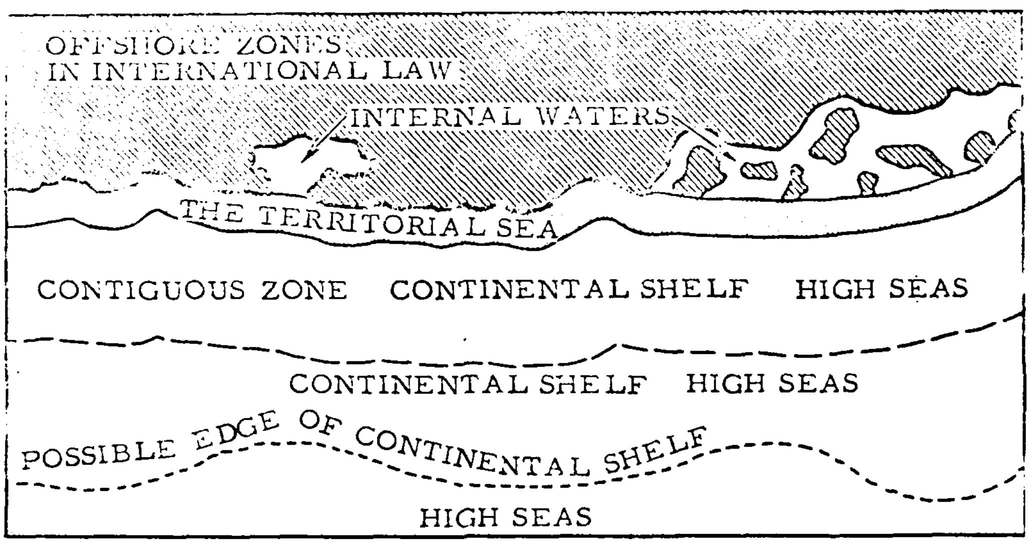
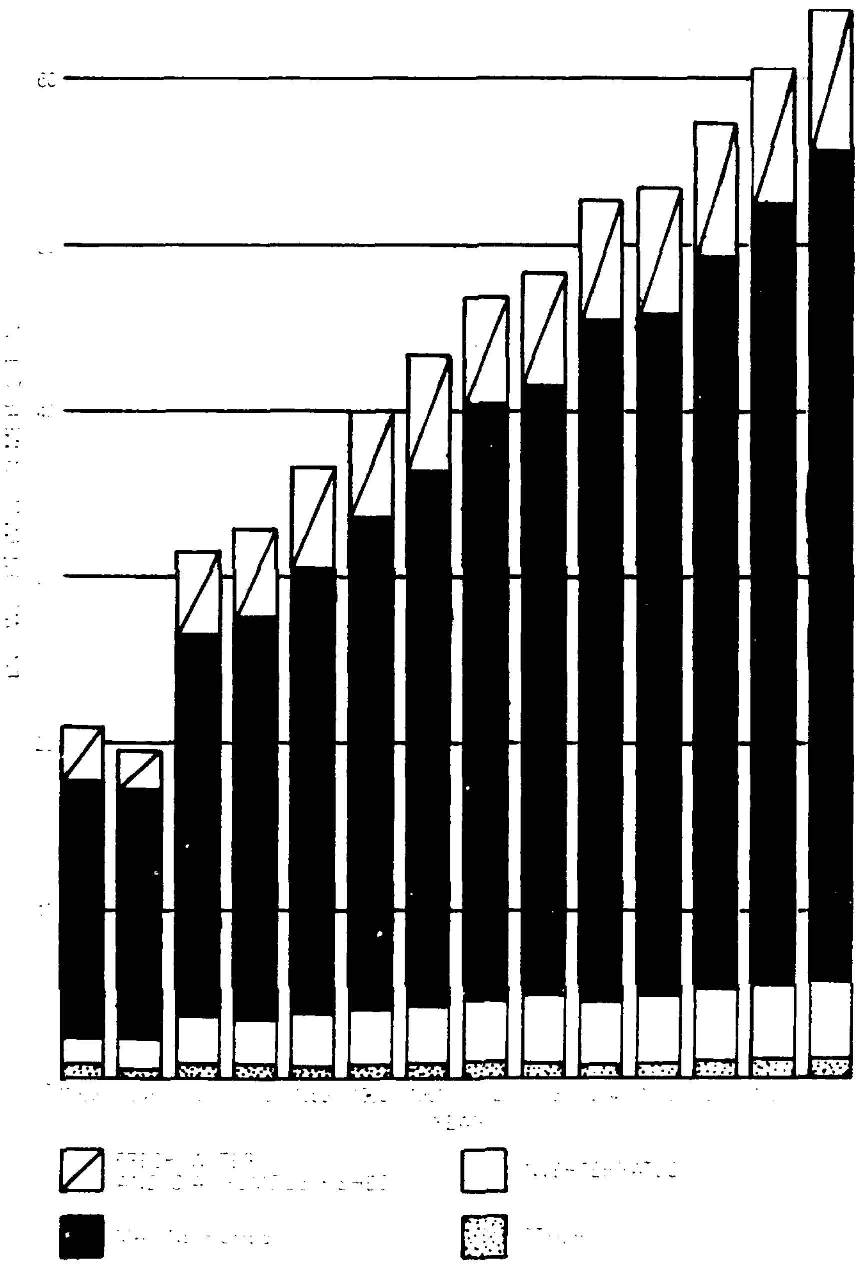


Figure 2. Concepts of Five Distinct Zones of Water. Attendant to Shorelines. Note that in some instances the zones overlap.



WORLD FISH CATCH has more than tripled in the three decades since 1938; the FAO estimate of the 1968 total is 64 million metric tons. The largest part (solid color) consists of marine fishes. Humans consume only half of the catch; the rest becomes livestock feed.

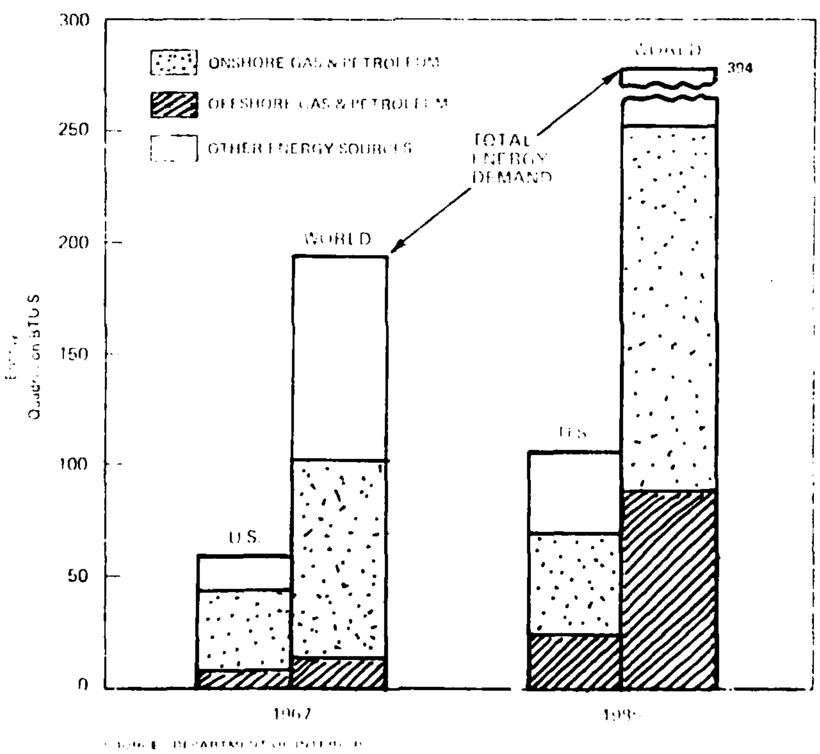
Figure 3

Table 1 - Growth in Selected Coastal Recreational Activities

Type of Recreation	Participants (millions) 1964	Participants (millions) 1975
Swimming	33	40
Surfing	1	4
Skin diving	1	3
Pleasure boating	20	50
Sport fishing	8	16
National Park and Forest Recreation	18	44

Source: Departments of Commerce, Interior, and Transportation

Figure 4. Projected Demand for Offshore Gas and Petroleum



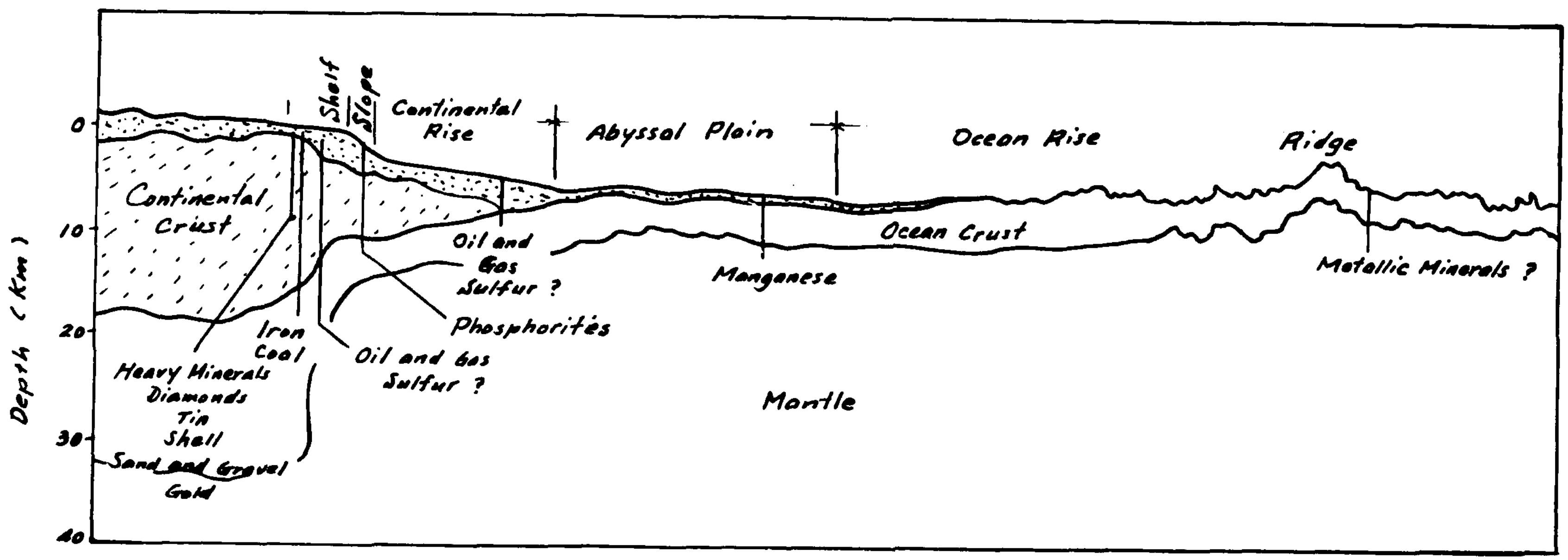


Fig. 5. Ocean Floor Resources

Number of Nations	Activities
9	Exploited offshore petroleum and gas resources
13	Exploited minerals from ocean water and seabed
7	Disposed of wastes in the ocean

Table 2a. United Nation's 1968 poll of 58 nations
(U. N. Intergovernmental Oceanographic Commission)

Table 2b

ELEMENT	TONS PER CUBIC MILE	ELEMENT	TONS PER CUBIC MILE
Chlorine	89,500,000	Nickel	9
Sodium	49,500,000	Vanadium	9
Magnesium	6,400,000	Manganese	9
Sulfur	4,200,000	Titanium	5
Calcium	1,900,000	Antimony	2
Potassium	1,800,000	Cobalt	2
Bromine	306,000	Cesium	2
Carbon	132,000	Cerium	2
Strontium	38,000	Yttrium	1
Boron	23,000	Silver	1
Silicon	14,000	Lanthanum	1
Fluorine	6,100	Krypton	1
Argon	2,800	Neon	.5
Nitrogen	2,400	Cadmium	.5
Lithium	800	Tungsten	.5
Rubidium	570	Xenon	.5
Phosphorus	330	Germanium	.3
Iodine	280	Chromium	.2
Barium	140	Thorium	.2
Indium	94	Scandium	.2
Zinc	47	Lead	.1
Iron	47	Mercury	.1
Aluminum	47	Gallium	.1
Molybdenum	47	Bismuth	.1
Selenium	19	Niobium	.05
Tin	14	Thallium	.05
Copper	14	Helium	.03
Arsenic	14	Gold	.02
Uranium	14		

CONCENTRATION of 57 elements in seawater is given in this table. Only sodium chloride (common salt), magnesium and bromine are now being extracted in significant amounts.

Year	Number of Vessels
1955	2,500
1965	3,500
1968	4,300

Table 3. World Tanker Fleet
*(Sibthorp ocean pollution)

	Western Europe	U.S.A.
Petro-chemicals	eightfold	-
Plastic	threefold	fourfold
Pharmaceuticals	threefold	-
Synthetic detergents	-	threefold
Pesticides	-	threefold

Table 4. Increase in production of pollutant chemicals during 1953-1960.

* (E/4457, AD 1, U. N. Doc.)

	Cost	Tonnage
Dredging spoils	53%	80%
Bulk industrial wastes	27%	10%
Sewage sludge	15%	9%
Construction debris	1%	1%
Containerized industrials	1%	1%
Refuse and garbage	< 1%	< 1%
Explosives (military)	< 1%	< 1%
Miscellaneous	< 1%	< 1%

Table 5a. Extent of U. S. ocean dumping in 1968.
*(Dillingham Env. Co. 1970)

Waste acids	2700×10^3 tons
Refinery wastes	560 x "
Pesticide wastes	330 x "
Paper Mill wastes	140 x "
Others	< 1 x "

* Ocean dumping (Env. Sci. & Tech. 1970)

Table 5b. Components of Industrial Wastes

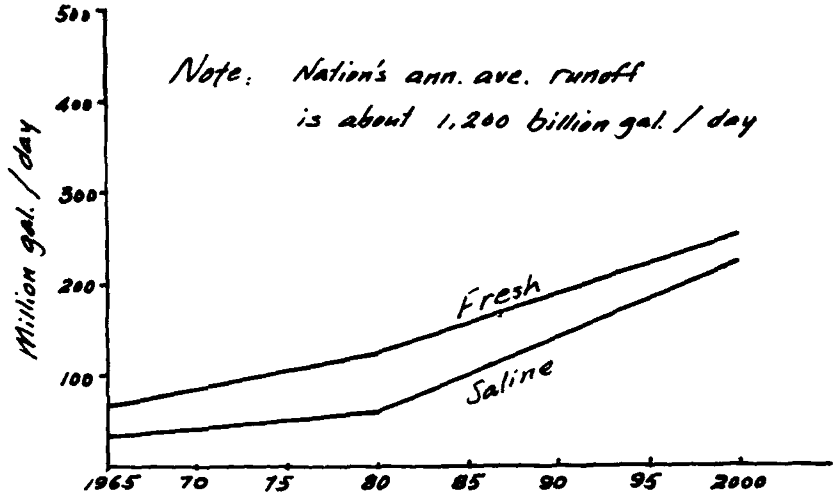


Fig. 6 Water requirements for utility owned steam electric plant

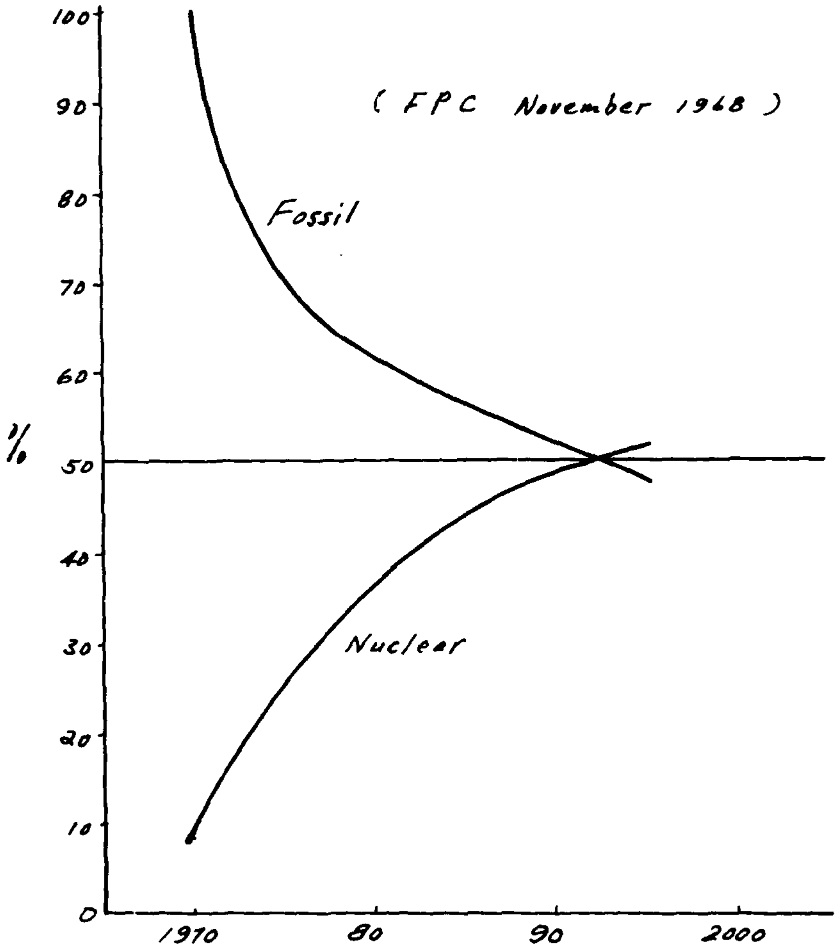


Fig. 7. Properties of total waste heat contributed by fossil and nuclear plants

Ship Type	Number	Average Oil Cargo Capacity (tons)	Average Bunker Oil Capacity (tons)
Foreign-Dry Cargo	34,000		1400
" Tanker	6,100	25,000	2500
U. S. Dry Cargo	7,000		3400
" Tanker	3,000	14,000	1300
TOTAL	50,100	300 million	

Table 6. Number of Visits to U. S. ports in FY 1966 by vessels over 1,000 dwt.
*(Marine Sci. Affair[14])

		FY 1966	FY 1967
Number of Casualties, all types		2,408	2,353
Vessel over 1,000 dwt		1,310	1,347
Tank ships & tank barges		470	499
Locations:	U. S. Waters	1,680	1,569
	Elsewhere	723	784
Types of casualties			
Collisions		922	1,090
Explosions		175	168
Grounding with damages		302	282
Founderings, capsizings & floodings		315	230

Table 7. Casualty record of U. S. registered vessels worldwide & foreign vessels in U. S. waters.
*(Marine Sci. Affair[14])

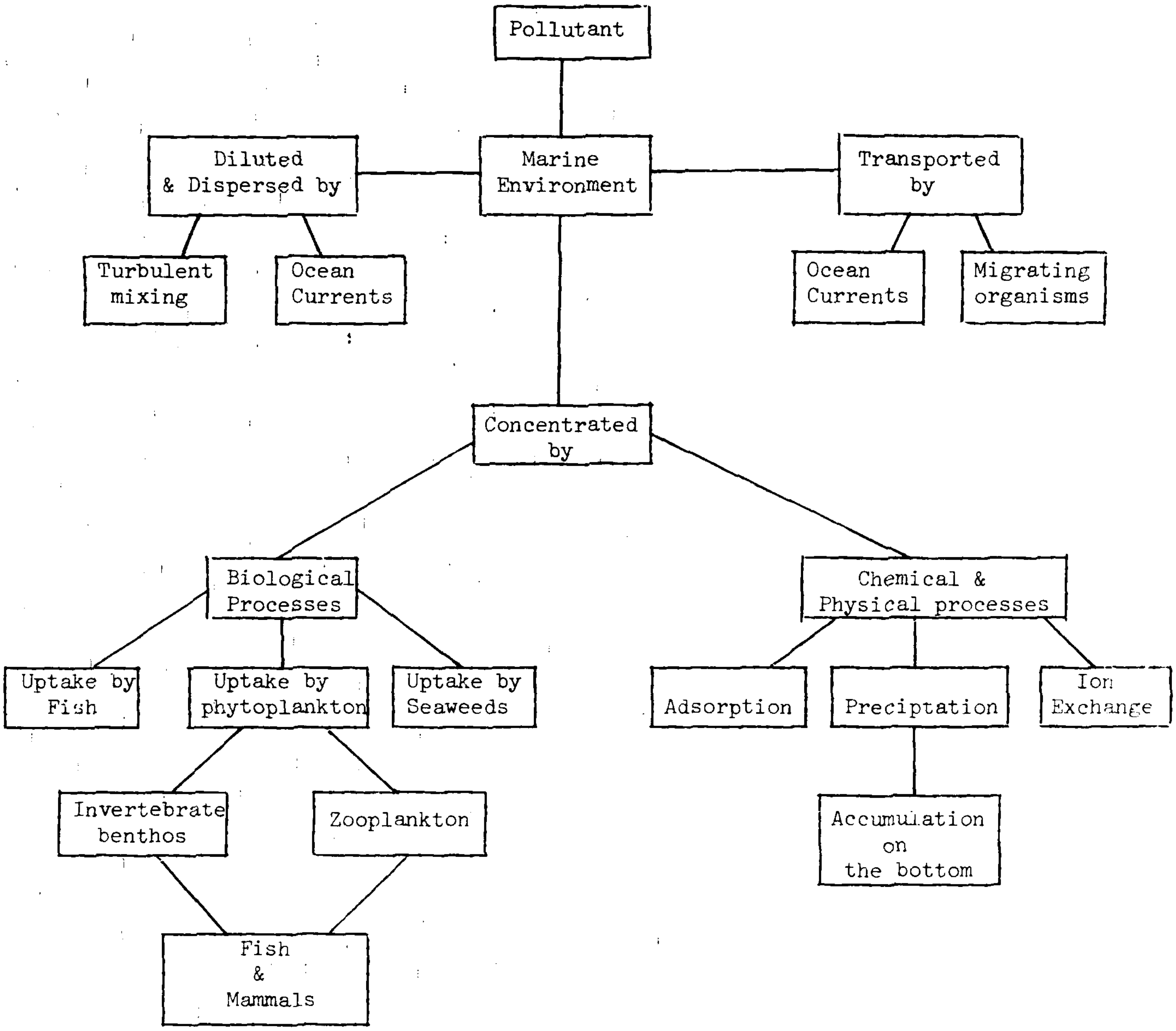


Figure 8. The various processes which determine the fate and distribution of a pollutant added to the marine environment. (From B. H. Ketchum, Pollution & Marine Ecology[50])

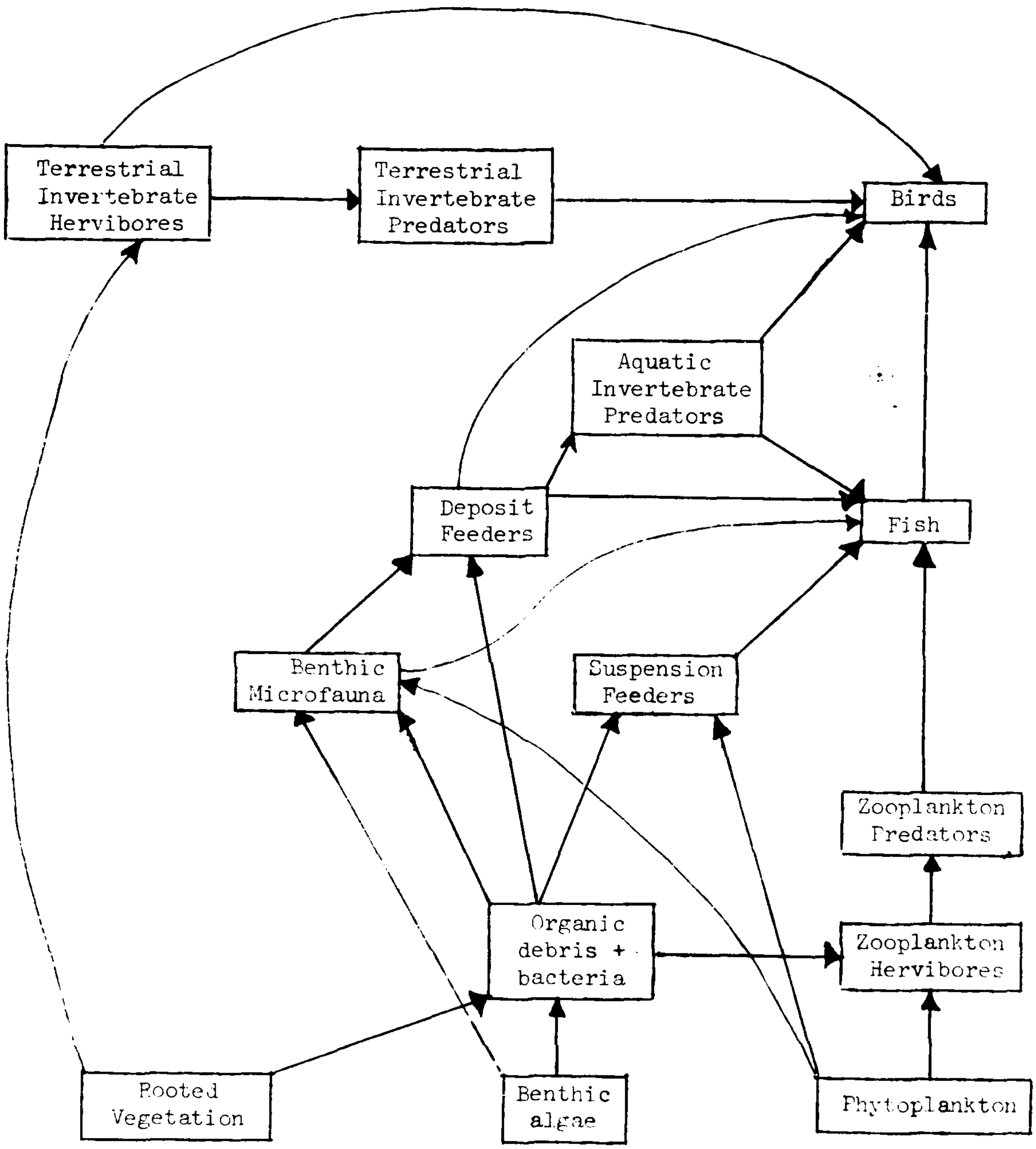
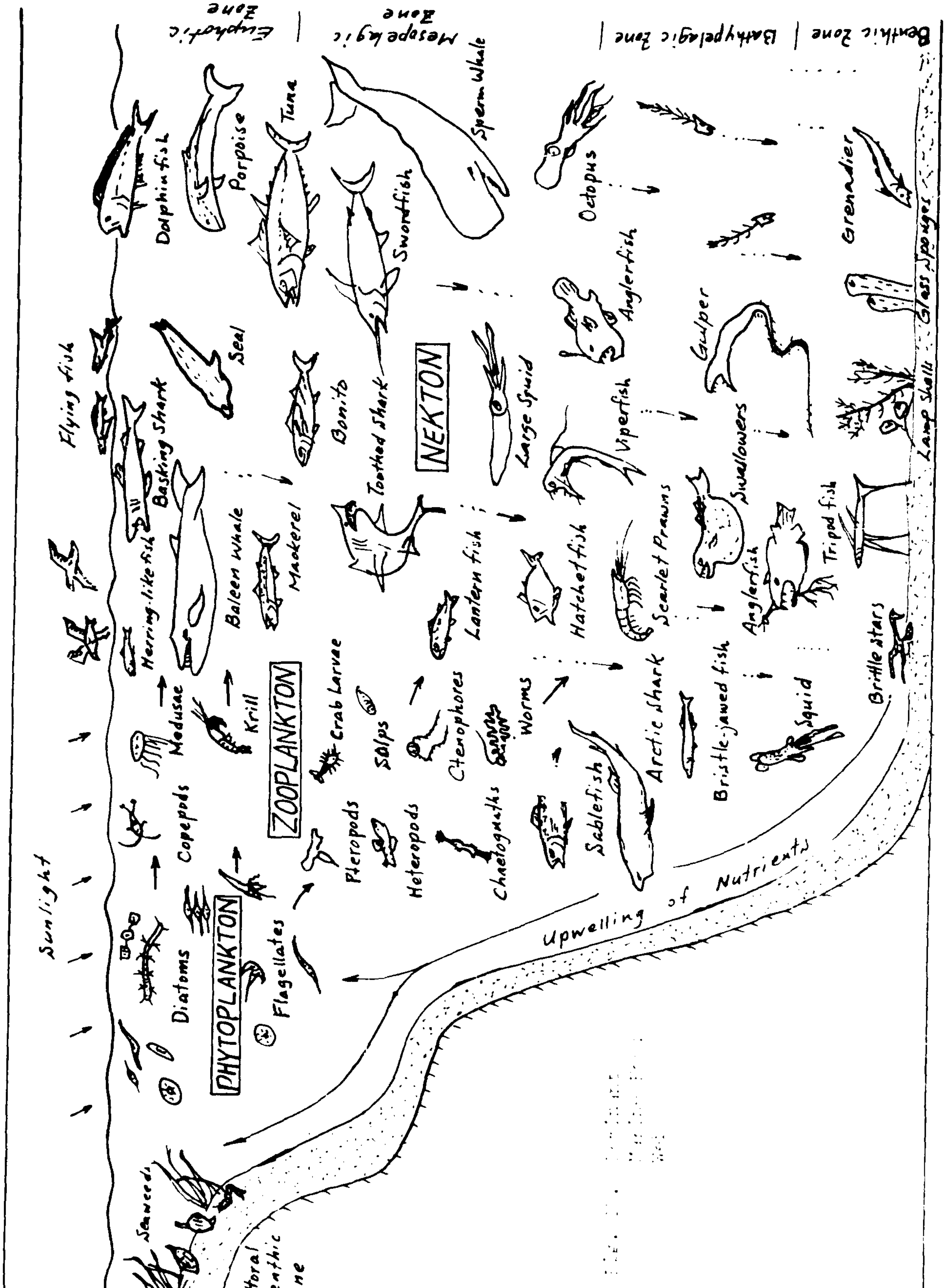


Figure 9. Diagram of the food relationships o the main ecological groups of estuarine animals.

*(J. Green, The Biology of Estuarine Animals)


Euphotic Zone
Mesopelagic Zone
Bathypelagic Zone
Benthic Zone
Sunlight
Seaweeds
Littoral Benthic Zone
PHYTOPLANKTON
Diatoms
Flagellates
ZOOPLANKTON
Copepods
Medusae
Krill
Pteropods
Heteropods
Salps
Crab Larvae
Ctenophores
Chaetognaths
Worms
NEKTON
Flying fish
Herring-like fish
Basking Shark
Baleen Whale
Mackerel
Seal
Bonito
Toothed Shark
Lantern fish
Dolphinfish
Porpoise
Tuna
Swordfish
Sperm Whale
Large Squid
Hatchetfish
Sablefish
Arctic Shark
Scarlet Prawns
Viperfish
Anglerfish
Octopus
Gulper
Swallowers
Anglerfish
Bristle-jawed fish
Squid
Tripod fish
Brittle stars
Grenadier
Lamp Shells
Glass Sponges
Upwelling of Nutrients

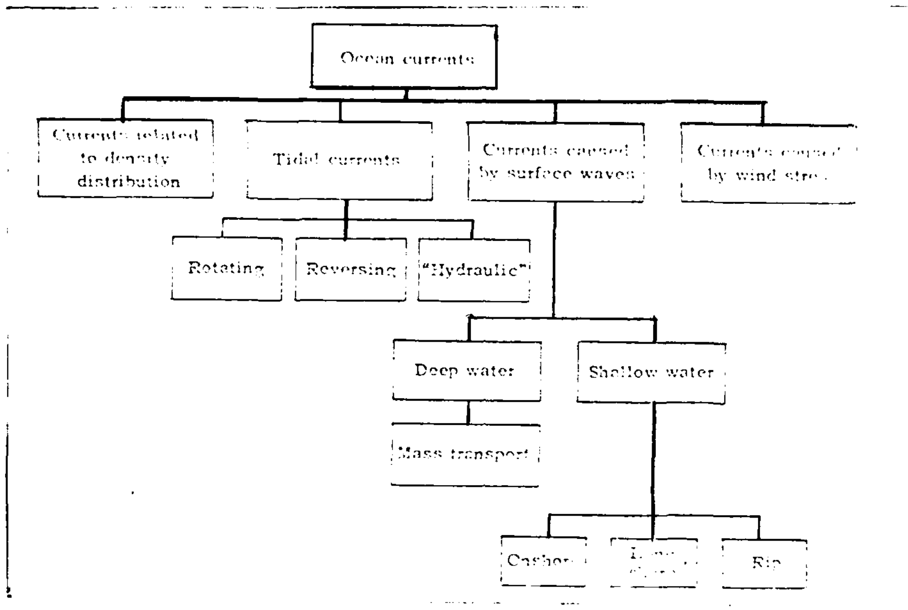


Fig. 12. Classification of Ocean Currents [3]

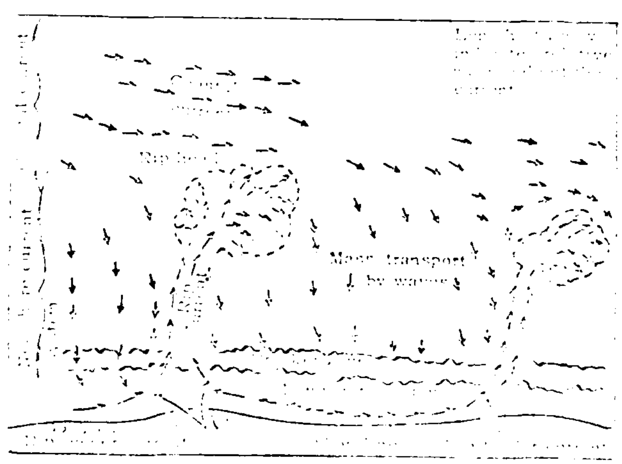


Fig. 13. Nearshore circulation pattern-three-dimensional case. (By permission from Shepard and Inman, Proc. First Conf. on Coastal Eng., Council on Wave Research, Berkeley, Calif., 1951.)

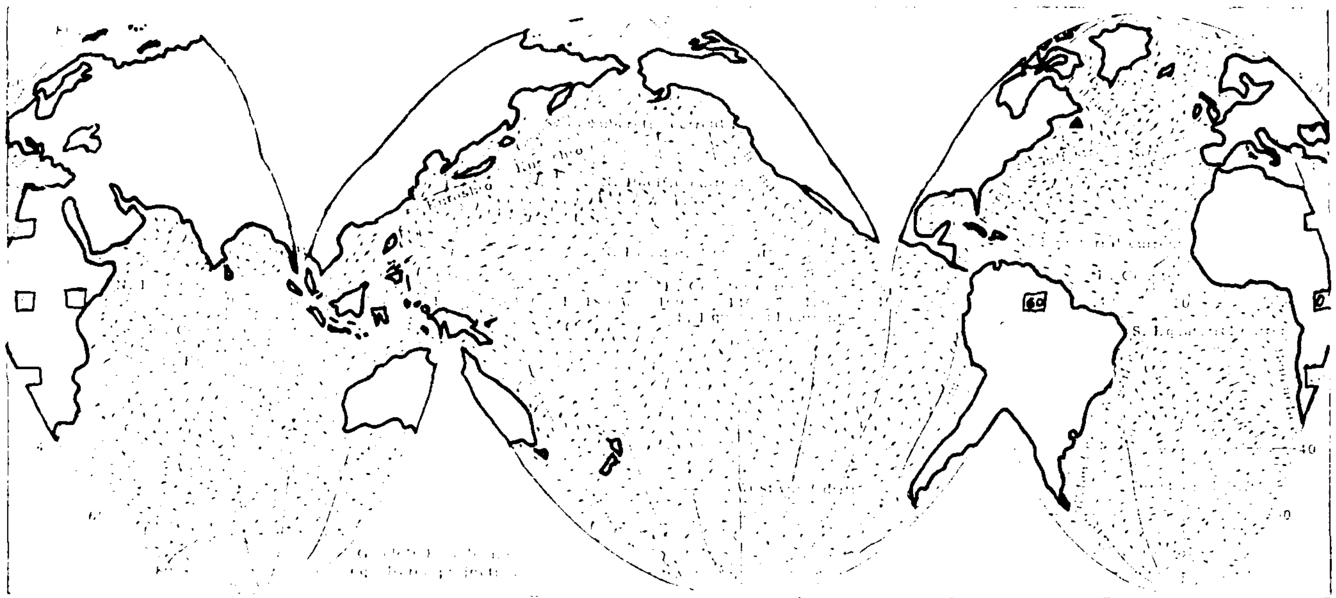


Figure 14. Surface currents of the oceans in February-March. (By permission from Sverdrup, Johnson and Fleming, "The Oceans, Their Physics, Chemistry, and General Biology," Copyright 1942, Prentice-Hall, Inc., Englewood Cliffs, New Jersey and from Goode Base Maps Series, Copyright by the University of Chicago, Department of Geography.)

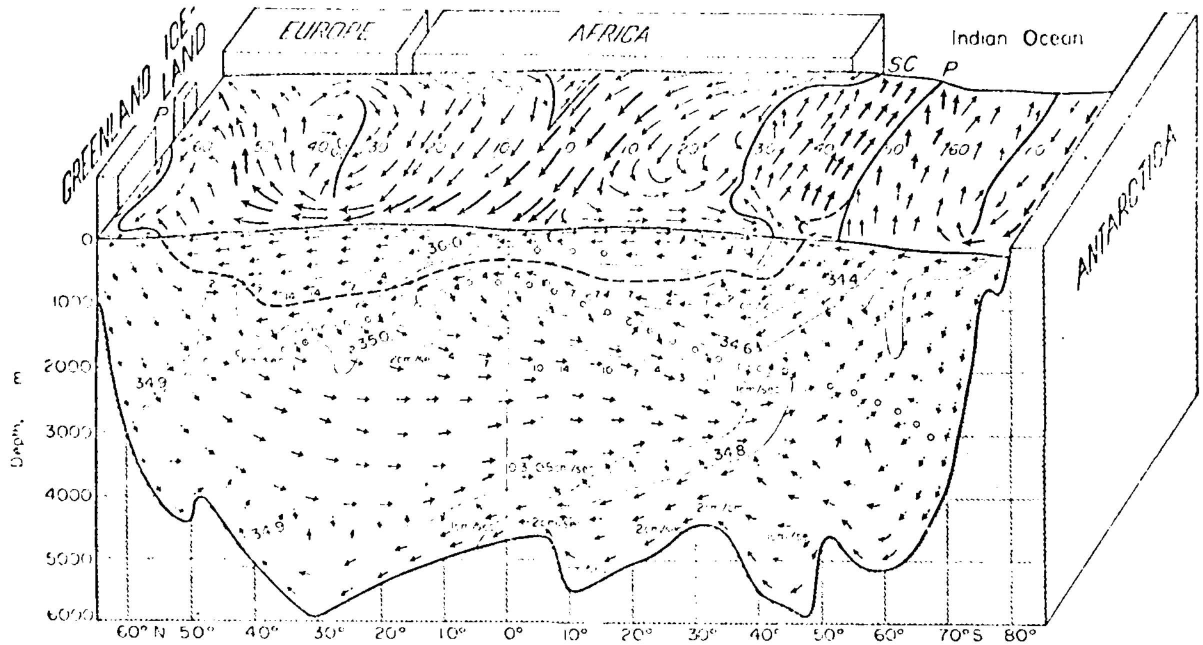


Fig. 15. Schematic block diagram of the surface currents and of the deep sea circulation of the Atlantic Ocean (according to Wüst).

(Physical Oceanography, Defaut, A.)

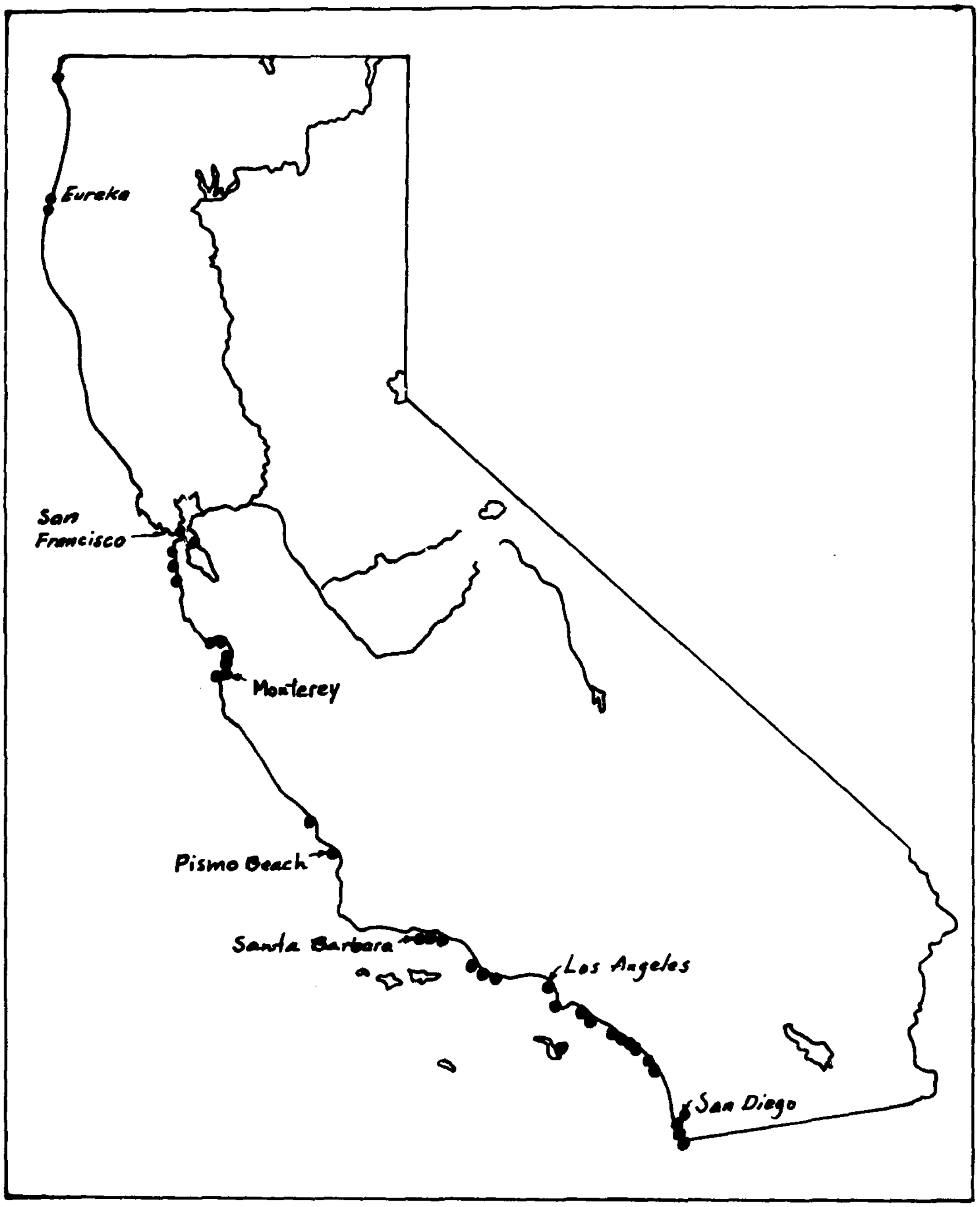


Figure 16. Major Submarine Outfalls in California

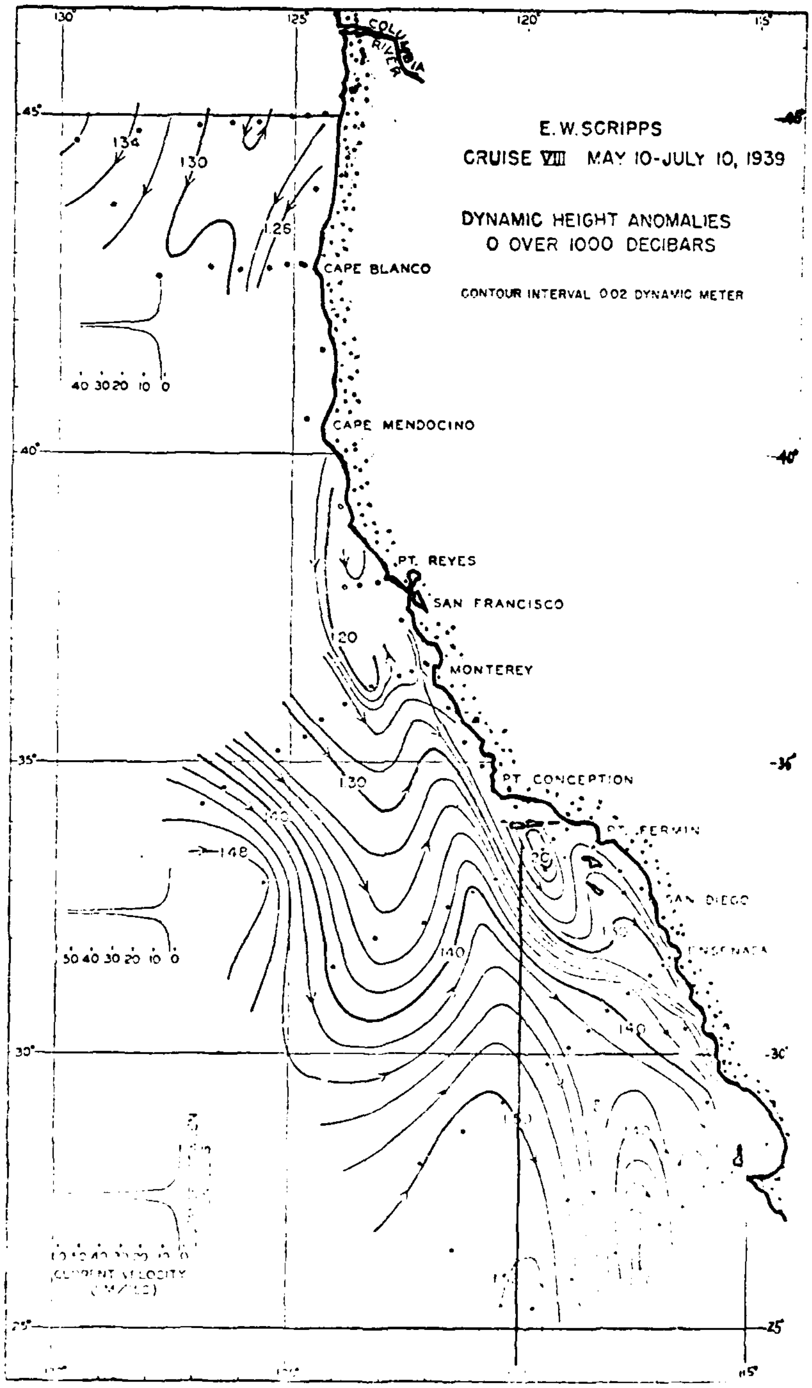


Figure 17. Geopotential topography of the sea surface relative to the 1000-decibar surface off the American west coast in May to July, 1939, showing flow alternating away from and towards the coast.

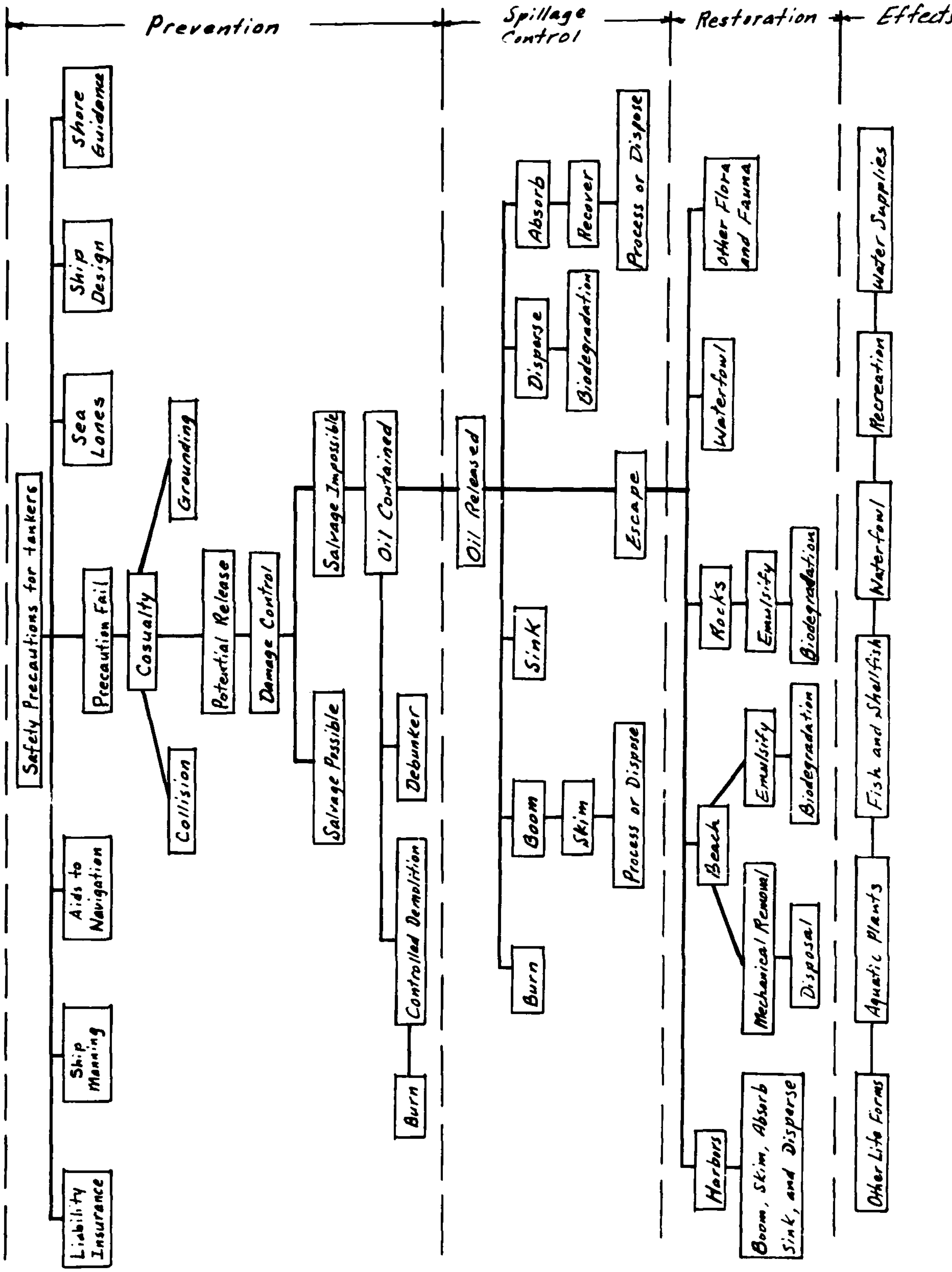


Fig. 15. Oil Spillage Prevention, Control, Restoration and Effects

FUNCTIONAL DESIGN

Table 9. Factors to be Considered in the Design of Marine Waste Disposal Systems (from Pearson, 1961)

I. Beneficial Uses

1. Water contact sports
2. Marine recreation, boating
3. Marine working environment
4. Fishery, propagation, migration, etc.
5. Economic fishery, propagation harvesting
6. Industrial commercial use, coding, etc.
7. Waste disposal
8. Other

II. Water Quality Criteria to Protect Beneficial Uses

1. Public Health
   (a) Coliform
   (b) Other
2. Fishery
   (a) Toxic substances
   (b) Antagonistic substances
   (c) Oxygen depressants
   (d) Stimulants, fertilizers
   (e) Transparency, turbidity
   (f) Suspended and settleable debris
3. Nuisance
   (a) Grease and oil films
   (b) Floating debris
   (c) Settleable debris
   (d) Odors
4. Aesthetic
   (a) Sleek areas
   (b) Colors
   (c) Turbidity--transparency
   (d) Floating debris
   (e) Plankton bloom
   (f) Other
5. Economic and other

III. Oceanographic Characteristics of Outfall Sites

1. General water circulation system
2. Current
   (a) Surface and subsurface
   (b) Strength and direction as a function of time
   (c) Effect of wind, wave, tide, littoral drift
3. Eddy diffusivity or dispersion characteristics
4. Density structure, salinity-temperature-depth relationship
5. Wave and swell effects
6. Submarine topography
7. Submarine geology

IV. Waste Dispersion Considerations

1. Initial mixing--diffuser
   (a) Jet mixing
   (b) Buoyancy--gravitational mixing
   (c) Density gradients--thermoclines
   (d) Diffuser orientation
   (e) Waste dilution--flow continuity
   (f) Port selection, area--spacing
2. Waste transport--dispersion
   (a) Current regiment
   (b) Eddy diffusion
   (c) Mixing depth, effective
   (d) Rational dispersion equations
      (1) Concentration dilution only--conservative waste
      (2) Concentration including decay--nonconservative waste, i.e., bacteria, radioisotopes, BOD, etc.

(continued next page)

Table 9 (continued)

V. Economic Analyses

1. Various types of treatment and effluent characteristics.
2. Length, depth, and cost of outfall systems for each type of effluent to meet water quality criteria requirements.
3. Selection of optimum and least-cost combination of treatment and outfall system to protect beneficial uses.

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